# The Journal of Bone and Joint Surgery

*The Official Publication of*
The American Orthopaedic Association
The British Orthopaedic Association
The American Academy of Orthopaedic Surgeons
The Australian Orthopaedic Association
The Canadian Orthopaedic Association
American Society for Surgery of the Hand
New Zealand Orthopaedic Association
South African Orthopaedic Association

JANUARY 1956

American Volume
Vol. 38-A, No. 1

8 THE FENWAY, BOSTON 15, MASSACHUSETTS, U. S. A.
BRITISH OFFICE:
82 PORTLAND PLACE, LONDON, W. 1, ENGLAND

# The Journal of Bone and Joint Surgery

PUBLISHED IN TWO VOLUMES

**The Journal of Bone and Joint Surgery**

AMERICAN VOLUME

*Editor*, and *Chairman* of the Board of Editors:
WILLIAM A. ROGERS

**American Board of Associate Editors**

DAVID M. BOSWORTH, New York, N. Y.
THORNTON BROWN, Boston, Massachusetts
EDWARD L. COMPERE, Chicago, Illinois
MARK B. COVENTRY, Rochester, Minnesota
HAROLD E. CROWE, Los Angeles, California
G. W. N. EGGERS, Galveston, Texas
DAVID S. GRICE, Boston, Massachusetts
KEENE O. HALDEMAN, San Francisco, California
CHARLES H. HERNDON, Cleveland, Ohio
ROBERT A. KNIGHT, Memphis, Tennessee
CARROLL B. LARSON, Iowa City, Iowa
MICHAEL L. MASON, Chicago, Illinois
JOHN ROYAL MOORE, Philadelphia, Pennsylvania
I. WILLIAM NACHLAS, Baltimore, Maryland
FRED C. REYNOLDS, St. Louis, Missouri
ROBERT A. ROBINSON, Baltimore, Maryland
DONALD B. SLOCUM, Eugene, Oregon

**The Journal of Bone and Joint Surgery**

BRITISH VOLUME

SIR REGINALD WATSON-JONES, *Editor*

**British Editorial Board**

PROFESSOR WALTER MERCER, *Chairman*
PHILIP WILES, *Treasurer*
H. JACKSON BURROWS, *Deputy Editor*
J. CRAWFORD ADAMS, *Assistant Editor*
J. M. P. CLARK, Leeds, England
ALEXANDER GILLIES, Wellington, New Zealand
D. J. GLISSAN, Sydney, Australia
D. LL. GRIFFITHS, Manchester, England
A. R. HAMILTON, Sydney, Australia
R. I. HARRIS, Toronto, Canada
A. J. HELFET, Cape Town, South Africa
F. W. HOLDSWORTH, Sheffield, England
K. I. NISSEN, London, England
H. OSMOND-CLARK, London, England
N. W. ROBERTS, Liverpool, England
J. EDOUARD SAMSON, Montreal, Canada
J. TRUETA, Oxford, England
DENYS WAINWRIGHT, Stoke, England

WILLIAM A. ROGERS, *Editor-in-Chief*

**Corresponding Editors**

*Argentina:* JOSÉ VALLS
*Austria:* WALTHER EHALT
*Belgium:* JEAN VERBRUGGE
*Brazil:* F. E. GODOY MOREIRA
*Cuba:* ALBERTO INCLÁN
*Denmark:* JOHANNES MORTENS
*Finland:* K. E. KALLIO
*France:* R. MERLE D'AUBIGNÉ
*Germany:* MATHIAS HACKENBROCH
*Italy:* O. SCAGLIETTI
*Mexico:* JUAN FARILL
*Netherlands:* J. D. MULDER
*Poland:* ADAM GRUCA
*Portugal:* ARNALDO RODO
*Sweden:* STEN FRIBERG
*Uruguay:* JOSÉ LUIS BADO

**Committees**

THE JOURNAL OF BONE AND JOINT SURGERY,
INCORPORATED

***The American Orthopaedic Association***

***The American Academy of Orthopaedic Surgeons***

BOARD OF TRUSTEES

ROBERT W. JOHNSON, JR., *Chairman*
EDWARD L. COMPERE, *Vice-Chairman*
GUY A. CALDWELL, *Secretary*
DAVID M. BOSWORTH, *Treasurer*
WILLIAM A. ROGERS, *Editor*
JAMES S. SPEED
H. RELTON MCCARROLL

***American Society for Surgery of the Hand***

*President:* S. BENJAMIN FOWLER
*President-Elect:* L. D. HOWARD
*Secretary-Treasurer:* GEORGE V. WEBSTER
960 East Green Street, Pasadena 1, California

***The Australian Orthopaedic Association***

T. KING, Melbourne, *President*
WARWICK STENING, Sydney, *Editorial Secretary*
F. H. MCC. CALLOW, *Secretary*, 141 Missenden Road,
Sydney, New South Wales

***The British Orthopaedic Association***

PHILIP WILES, *President*
T. J. FAIRBANK, *Editorial Secretary*
J. I. P. JAMES, *Secretary*
45 Lincoln's Inn Fields, London, W.C.2

***The Canadian Orthopaedic Association***

ALEXANDER GIBSON, Winnipeg
ROBERT I. HARRIS, Toronto
J. EDOUARD SAMSON, Montreal
F. P. PATTERSON, Vancouver
WILLIAM B. MACKINNON, *Secretary*
661 Broadway, Winnipeg, Manitoba

***New Zealand Orthopaedic Association***

MORRIS AXFORD, Auckland, *President*
HARMAN SMITH, Auckland, *Secretary*
ALAN ALLDRED, Dunedin
J. K. CUNNINGHAME, Wellington
N. NISBET, *Editorial Secretary*
Dunedin Hospital, Dunedin C.1, New Zealand

***South African Orthopaedic Association***

C. T. MOLLER, *President*
W. T. ROSS, *Treasurer*
SIDNEY SACKS, *Secretary*
1010 Medical Centre
Johannesburg, South Africa

**Published in the United States by
The Journal of Bone and Joint
Surgery, Incorporated**

**Copyrighted in the United States by
The Journal of Bone and Joint
Surgery, Incorporated**

**Published in the United Kingdom for The British
Editorial Society of Bone & Joint Surgery Limited by
E. & S. Livingstone, Teviot Place, Edinburgh**

**Copyright in Britain and the Commonwealth by
The British Editorial Society of Bone &
Joint Surgery Limited**

THE JOURNAL OF BONE AND JOINT SURGERY

***American Office***
**8 The Fenway, Boston 15, Massachusetts, U.S.A.**
***Managing Editor:* John A. Reed**

***British Office***
**82 Portland Place, London, W. 1, England**
***Editorial Secretary:* Jean Barnes**

# The Journal of Bone and Joint Surgery*

*American Volume*

## TABLE OF CONTENTS

January 1956

PAGE

Recurrent Dislocation of the Shoulder. A Twenty-Four Year Study of the Johannesburg Stapling Operation.
By *G. T. du Toit, F.R.C.S.(Eng.)*, and *D. Roux*, Johannesburg, South Africa .................. 1

Combined Hip Fusion and Subtrochanteric Osteotomy Allowing Early Ambulation.
By *Frederick R. Thompson, M.D.*, New York, N. Y. .................. 13

Internal Fixation in Displaced Intracapsular Fractures of the Femoral Neck.
By *George O. Eaton, M.D.*, Baltimore, Maryland .................. 23

Osteotomy and Osteotomy Combined with Bone-Grafting for Non-Union Following Fracture of the Femoral Neck.
By *Marcus J. Stewart, M.D.*, and *R. E. Wells, M.D.*, Memphis, Tennessee .................. 33

Posterior Arthrodesis of the Ankle and Subtalar Joints.
By *O. Sherwin Staples, M.D.*, Hanover, New Hampshire .................. 50

The Mechanism of Ankle Injuries.
By *Barnard Kleiger, M.D.*, New York, N. Y. .................. 59

The Pathology of Slipping of the Upper Femoral Epiphysis.
By *Ignacio V. Ponseti, M.D.*, and *Robert McClintock, M.D.*, Iowa City, Iowa .................. 71

A Study of Experimental Trauma to the Distal Femoral Epiphysis in Rabbits.
By *Lee T. Ford, M.D.*, and *J. Albert Key, M.D. (deceased)*, St. Louis, Missouri .................. 84

Vertebral-Body Biopsy.
By *Frederick S. Craig, M.D.*, New York, N. Y. .................. 93

Immunological Factors in Homogenous-Bone Transplantation. I. Serological Studies.
By *Paul H. Curtiss, Jr., M.D.*, and *Charles H. Herndon, M.D.*, Cleveland, Ohio .................. 103

Repair of Defects in the Tendo Achillis.
By *David M. Bosworth, M.D.*, New York, N. Y. .................. 111

Hemangiomatosis of the Skeleton and the Spleen.
By *Gorton Ritchie, M.D.*, Milwaukee, Wisconsin, and *Francis G. Zeier, M.D.*, Rockford, Illinois 115

Possible Mechanism of Aortic Rupture in Orthopaedic Correction of Rheumatoid Spondylitis.
By *Philip O. Lichtblau, M.D.*, and *Philip D. Wilson, M.D.*, New York, N. Y. .................. 123

(*Continued on page 3*)

*The Journal of Bone and Joint Surgery* (American Volume) is issued six times a year—in January, April, June, July, October, and December. The 1956 subscription price, payable in advance, is $13.00. Single copies $2.50.

*The Journal of Bone and Joint Surgery*, entered as second-class matter August 1, 1921, at the Post Office, Boston, Mass., under the act of March 3, 1879. Editorial and business offices, 8 The Fenway, Boston, Mass. Accepted at the special rate of postage provided for in the act of February 28, 1925, Paragraph 4, Section 412, Postal Laws and Regulations; authorized April 21, 1932. Additional entry at Concord, New Hampshire, authorized June 10, 1947.

Copyright 1956 by *The Journal of Bone and Joint Surgery, Incorporated*

* TITLE REGISTERED IN UNITED STATES PATENT OFFICE

# *The Journal of Bone and Joint Surgery* WELCOMES ARTICLES WHICH CONTRIBUTE TO SURGICAL SCIENCE FROM ALL COUNTRIES OF THE WORLD

Manuscripts submitted for publication in the AMERICAN VOLUME should be sent to The Editor, *The Journal of Bone and Joint Surgery*, 8 The Fenway, Boston 15, Massachusetts.
Manuscripts submitted for publication in the BRITISH VOLUME should be sent to The Editor, *The Journal of Bone and Joint Surgery*, 82 Portland Place, London, W.1, England.

---

## INFORMATION FOR CONTRIBUTORS TO THE AMERICAN VOLUME

- Articles are accepted only for exclusive publication in *The Journal of Bone and Joint Surgery*.
- Publication does not constitute official endorsement of opinions presented in articles.
- Articles published and their illustrations become the property of *The Journal*.

*Careful attention to the following suggestions can save much time and correspondence.*

### WHEN YOU SUBMIT AN ARTICLE PLEASE SEND:

1. THE ORIGINAL MANUSCRIPT. Keep a copy. The original manuscript of an accepted article will not be returned. Several editors report on every manuscript. One or two extra copies sent to us will accelerate this procedure.
2. BIBLIOGRAPHY, alphabetical, of references made in text *only*. Please refer to bibliographies in this copy of *The Journal* and follow style exactly.
3. LEGENDS for all illustrations submitted, listed in order.
4. ILLUSTRATIONS
    - a. *Black and white glossy prints* of photographs.
    - b. *Direct-contact glossy prints* from the original roentgenograms, not prints from secondary negatives.
    - c. *Original* drawings or charts.
    - d. *Magnification* of photomicrographs.

### NOTES ON PREPARATION OF MANUSCRIPT

- Manuscripts must be typewritten, double-spaced with wide margins.
- Write out figures under 100 except percentages, degrees, or figures expressed in decimals.
- Direct quotations should include exact page numbers on which quotation appeared in book or article.

### NOTES ON PREPARATION OF ILLUSTRATIONS

- Number all illustrations.
- Indicate *top* plainly.
- Write author's name on the back of each one.
- Put dates or initials in *Legends*, not on prints.
- Send prints unmounted or mounted only with rubber cement. Paste or glue will damage prints.
- Drawings, charts, and lettering on prints should be done with black India ink. Use white India ink on black backgrounds.
- Make lettering large enough to be read when drawings are reduced.
- When submitting an illustration which has appeared elsewhere give full information about previous publication, credit to be given, and state whether or not permission to reproduce has been obtained.

### COPYRIGHT

Material appearing in *The Journal* is covered by copyright. As a general rule permission will be given to reputable medical journals to reprint anything in these pages, if permission is first obtained from *The Journal* and if the material used is properly credited to *The Journal*.

### FOR ADDITIONAL INFORMATION, PLEASE WRITE TO THE EDITOR

# TABLE OF CONTENTS

*(Continued from page 1)*

PAGE

Developmental Anomaly of the Lateral Malleolus Simulating Fracture.
By *R. G. B. Bjornson, M.D.*, New York, N. Y. .......... 128

Osteochondrodystrophy as a Result of or in Relation to Pseudo-Hypoparathyroidism.
By *George J. Garceau, M.D.*, and *Wallace E. Miller, M.D.*, Indianapolis, Indiana .......... 131

Operative Treatment of Osteochondritis of the Tibial Tubercle.
By *J. E. M. Thomson, M.D.*, Lincoln, Nebraska .......... 142

The Etiology of Pre-Adolescent Kyphosis.
By *Albert Barnett Ferguson, Jr., M.D.*, Pittsburgh, Pennsylvania .......... 149

Avulsion of the Insertion of the Biceps Brachii. Report of a Case.
By *W. R. Fischer, M.D.*, and *L. A. Shepanek, M.D.*, Chicago, Illinois .......... 158

Bone Metabolism. II. Toxicity and Metabolism of Radioactive Strontium ($Sr^{90}$) in Rats.
By *Robert D. Ray, M.D., Ph.D.; Duncan M. Thomson, Ph.D.; Norvelle K. Wolff, M.S.;* and *Duane LaViolette, B.S.*, Seattle, Washington .......... 160

Late Effects (Twenty-Five to Forty Years) of the Early Medical and Industrial Use of Radioactive Materials. Their Relation to the More Accurate Establishment of Maximum Permissible Amounts of Radioactive Elements in the Body. Part II.
By *Lieutenant W. B. Looney*, Medical Corps, United States Naval Reserve .......... 175

An Improved Prosthesis for a Syme Amputation.
By *Rex L. Diveley, M.D.*, and *Richard H. Kiene, M.D.*, Kansas City, Missouri .......... 219

A Fracture Cart.
By *Ralph T. Lidge, M.D.*, Chicago, Illinois .......... 222

Functional Wrist Splint.
By *Odon F. von Werrsowetz, M.D.; Randolph N. Witt, Certified Orthotist;* and *Rose Elliott, B.A., O.T.R.*, Gonzales, Texas .......... 224

An Instrument for Use in Extracting Rush Pins.
By *Ben Fox, M.D.*, Marion, Illinois, and *Kenneth Van Lente, Ph.D.*, Carbondale, Illinois .......... 225

A Practical Method for Extracting Impacted Intramedullary Nails.
By *Wayne O. Southwick, M.D.*, and *George N. Austin, M.D.*, Baltimore, Maryland .......... 226

Proceedings:

Dedication of the New Hospital for Special Surgery .......... 227

New Jersey Orthopaedic Society .......... 232

The American Orthopaedic Association .......... 234

Kellogg Speed .......... 245

News Notes .......... 247

List of Advertisers .......... Adv. 51

Addresses of Contributors .......... Cover III

---

*Subscription Rates for 1956*
**AMERICAN AND BRITISH VOLUMES — Combination price $20.00 or £6.00.0**
**American Volume, $13.00 or £4.00.0** — **British Volume, £3.00.0 or $10.00.**
**Published January, April, June, July, October, December** — **Published February, May, August, November**
**All subscription rates include postage.**
**Checks should be made payable to *The Journal of Bone and Joint Surgery, Inc.***
***Microfilms of the American Volumes are available to regular subscribers through University Microfilms, 313 North First Street, Ann Arbor, Michigan.***

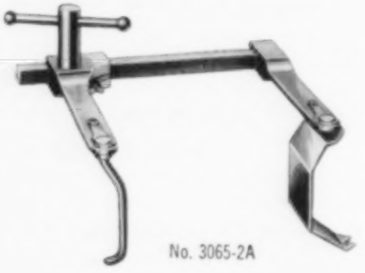
**THE JOURNAL OF BONE AND JOINT SURGERY**
***American Office*** — ***British Office***
**8 The Fenway, Boston 15, Massachusetts, U. S. A.** — **82 Portland Place, London, W. 1, England**

# Zimmer Instruments and Appliances for Orthopedic Surgery

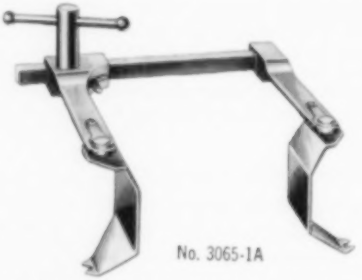
## THE EICHER FEMORAL PROSTHETIC HEAD NOW AVAILABLE IN TITANIUM

In order to make this prosthesis available for those doctors who want to use it made of Titanium, we have in stock the various sizes as listed. These are made from drop forged one-piece commercially pure Titanium. A paper written by Floyd H. Jergensen, M.D., of San Francisco, "The Use of Titanium Prosthetically in Orthopaedic Surgery," is available upon request.

No. 4530—Head sizes available—41, 43, 45 and 47 MM



No. 3065-2A



No. 3065-1A

## DOWNING LAMINECTOMY AND HEMILAMINECTOMY RETRACTORS

as designed by F. Harold Downing, M.D., Fresno, California

No. 3065-1A Downing Laminectomy Retractor @ $62.00
No. 3065-2A Downing Hemilaminectomy Retractor @ $61.00

The frame of this retractor is universal so that blades or hooks in three sizes may be purchased.

LEINBACH Contour Type MEDULLARY SCREWS
For Fixation of Fractures of the Olecranon Process
SMo Stainless Steel

Designed by Dr. Irwin S. Leinbach, St. Petersburg, Fla.

No. 517A, Large 6"—$8.50 ea.
No. 517B, Medium 5"—$8.00 ea.
No. 517C, Small 4"—$7.50

**ZIMMER MANUFACTURING CO. WARSAW, IND.**

Zimmer

In Canada Available through selected surgical supply dealers or through our Agents, Fisher & Burpe, Ltd.

Look for the trademark (Z)

introducing **DUROCEL**®

*The first important advance in the construction of immobilizing casts since the advent of plaster-of-paris bandage.*

## plastic foam bandage for orthopedic use

### NEW Comfort for patients

As a base for plaster casts, Durocel eliminates the need for stockinette, sheet wadding and other types of padding. It is more comfortable, non-toxic and non-irritating. Skin surfaces stay perfectly normal and healthy.

### NEW Convenience for Surgeons

Application of Durocel is exceptionally easy. It is applied directly to the skin and conforms readily to contours. Casts may be bi-valved, autoclaved and re-applied. Made in 2", 3", 4", 6" and 12" rolls. Send for full information and sample.

A PRODUCT OF ELKINS-EWALL,
PHILADELPHIA • BALTIMORE
PATENT PENDING

ZIMMER MANUFACTURING CO.
WARSAW, IND.

*Zimmer*

Look for the trademark Z

In Canada Available through selected surgical supply dealers or through our Agents, Fisher & Burpe, Ltd.

# A Laboratory and Clinical Report on Adrenosem® Salicylate

(BRAND OF CARBAZOCHROME SALICYLATE)

## History

The first investigation of a hemostat with an action comparable to Adrenosem Salicylate was made by Derouaux and Roskam[1] in 1937. They reported that an oxidation product of adrenalin, adrenochrome (which has no sympathomimetic properties), has prompt hemostatic activity.

It was further found that various combinations of adrenochrome, notably the oxime and semicarbazone, produced stable solutions. But, these were so slightly soluble that sufficient concentration could not be obtained for practical therapeutic use. By combining these adrenochrome compounds in a sodium salicylate complex a stable, soluble form can be obtained. This complex has been given the generic name, carbazochrome salicylate, and is supplied under the trade name Adrenosem Salicylate.

Roskam, in his study entitled "The Arrest of Bleeding,"[2] enumerates "the drugs whose efficaciousness as hemostatics have been proved by accurate methods in experimental animals and in healthy men as well. . . . One is the monosemicarbazone of adrenochrome [Adrenosem Salicylate]."

## Chemistry

Adrenosem Salicylate is a synthetic chemical. The full chemical name is adrenochrome monosemicarbazone sodium salicylate complex.

## Pharmacology

Although it is chemically related to epinephrine, Adrenosem Salicylate has no sympathomimetic effects. It does not alter blood components, nor does it affect blood pressure or cardiac rate.[2-7]

Sherber, in an early study,[3] concludes that Adrenosem Salicylate* "is a potent antihemorrhagic factor in those conditions in which the integrity of the smaller vessels is interrupted, and is superior to any similar material that is now available."

He continues, "From our experience it appears that adrenochromazone complex is indicated in preventing vascular accidents incident to hypertension; in maintaining small vessel integrity; in the preoperative preparation where oozing from a vascular bed is anticipated, as in tonsillectomies, adenoidectomies and prostatectomies; and as an adjunct in the treatment of bleeding from such surgical procedures."

Adrenosem Salicylate may be administered simultaneously (but separately) with any type of anesthetic, anticoagulant, or vitamin K and heparin.

## A Unique Systemic Hemostat

Clinical investigators[2-7] are in agreement that Adrenosem Salicylate controls bleeding and oozing by decreasing capillary permeability and by promoting the retraction of severed capillary ends. It aids in maintaining normal capillary integrity by direct action on the intercellular "cement" in capillary walls. The interesting work of Fulton[8] confirms this. Adrenosem Salicylate, since it is not a vasoconstrictor, has no effect on large severed blood vessels and arterioles.

Adrenosem Salicylate is being used both prophylactically and therapeutically in thousands of hospitals, and in virtually every type of surgical procedure. It has also proved most useful in dental surgery.[7]

Owings reported on the use of Adrenosem Salicylate in controlling postoperative adenoid bleeding in 102 cases.[4] "We have used 2½ mg.

---

(* U.S. Patent 2,581,850)

(½ ampule) intramuscularly, 15 minutes before anesthesia for children and 5 mg. (1 ampule) for adults." In only one patient did bleeding occur. Three others showed red blood from the nose and mouth. These patients "were then given 5 mg. intramuscularly, with prompt and complete control. We have also noticed that bleeding stopped more promptly on the operating table."

This is a 1% incidence of postoperative bleeding using Adrenosem Salicylate preoperatively, compared to an incidence of 10% postoperative bleeding in all cases taken from previous records, without Adrenosem Salicylate medication.

Peele reports on the use of Adrenosem Salicylate in treating 178 patients with 24 different conditions.[5] The drug was first used to control postoperative hemorrhage from the adenoid region. He adds: "The results were so dramatic that since that date [1953] Adrenosem Salicylate has been used postoperatively to reduce bleeding from all otolaryngologic and bronchoesophagolic procedures, to treat postoperative hemorrhage from the tonsil and adenoid regions, and to treat selected cases of epistaxis."

The effectiveness of Adrenosem Salicylate in controlling bleeding and oozing in 330 patients is reviewed by Bacala.[6] "Our experience of the effect of carbazochrome salicylate on 317 surgical indications and 13 obstetricogynecological conditions, has been therapeutically encouraging and successful for the control of capillary bleeding. Foremost among the cases studied were 223 tonsillectomies definitely benefited by this metabolic hemostat, making a diminution of the control incidence of posttonsillectomy bleeding of 19.8% down to 7%. It has also been found useful in gastro-intestinal bleeding, cataract extraction, epistaxis, incisional seepage, trans-urethral prostatectomy, menometrorrhagias, cervical ooze, antepartum and postpartum bleeding, threatened abortion, and prevention of capillary hemorrhages during hedulin or dicumerol therapy."

## Side Effects

All investigators concur that, at recommended dosage levels, Adrenosem Salicylate is free from toxic effects. No cumulative effects attributable to the drug have been reported.

The only side reaction noted has been a transient stinging sensation in the area of injection when Adrenosem Salicylate is used intramuscularly. As one investigator comments: "The brief discomfort which attends the injection of Adrenosem into the gluteal region has not been a significant problem in children or adults as originally anticipated."[5]

## Indications

Idiopathic purpura, retinal hemorrhage, familial telangiectasia, epistaxis, hemoptysis, hematuria.

Postoperative bleeding associated with:
tonsillectomy, adenoidectomy and
nasopharynx surgery;
prostatic and bladder surgery;
uterine bleeding;
postpartum hemorrhage;
dental surgery;
chest surgery and chronic pulmonary bleeding.

## Dosage

For recommended dosage schedules, please send for detailed literature.

## Supplied

Ampuls: 5 mg., 1 cc. (package of 5).
Tablets: 1 mg. S.C. Orange, bottles of 50.
Tablets: 2.5 mg. S.C. Yellow, bottles of 50.
Syrup: 2.5 mg. per 5 cc. (1 tsp.), 4 ounce bottles.

## References

1. Roskam, J. and Derouaux, G.: Arch. of Intern. Pharmacodynamie **71**:389 (1945).
2. Roskam, J.: Arrest of Bleeding, Charles C. Thomas, Springfield, Ill. 1954.
3. Sherber, Daniel A.: The Control of Bleeding. Am. J. Surg. **86**:331 (1953).
4. Owings, Capers B.: The Control of Postoperative Bleeding with Adrenosem, Laryngoscope, **55**:21 (Jan., 1955).
5. Peele, J.C.: Adrenosem in the Control of Hemorrhage from the Nose and Throat, A.M.A. Arch. of Otolaryng. **61**:450 (April, 1955).
6. Bacala, J.C.: The Use of the Metabolic Hemostat, Adrenosem Salicylate. To be published.
7. Riddle, A.C. Jr.: Adrenosem Salicylate: A Systemic Hemostat, Oral Surg., Oral Med., Oral Path. **6**:617 (June, 1955).
8. Fulton, M.D., Dept. of Biology, Boston University: Personal Communication.

THE S. E. MASSENGILL COMPANY • BRISTOL, TENNESSEE
NEW YORK KANSAS CITY SAN FRANCISCO

*FOR GREATER STRENGTH AND SAFETY —*

*DEMAND GENUINE* **NEUFELD NAILS** *and* **SCREWS**

*— IN* **NEUTRILIUM®**

*NEUTRILIUM®* is the most non-corrosive metal known to science. Its proven super-strength lends an assurance of permanence to internal fixation of the trochanteric area. This neutral, non-magnetic, homogenetic alloy is entirely inert and therefore compatible with human bone or tissue, remaining unaffected by body chemistry.

NEUFELD BONE SCREWS — of *NEUTRILIUM®* — are cold forged and, unlike other metals, appear to be unbreakable under maximum human pressures. Heads will not twist off during application or in actual use.

GENUINE NEUFELD NAILS and SCREWS — of *NEUTRILIUM®* — made only by MEDICAL RESEARCH SPECIALTIES, Loma Linda, California, are sold nationally by leading surgical and orthopaedic supply dealers.

*NEUTRILIUM® is a registered Trade Name of Medical Research Specialties.*

**NEUFELD FEMORAL NAIL PLATE**

Used for internal fixation of intertrochanteric and subtrochanteric fractures.

Write for descriptive literature

**MEDICAL RESEARCH SPECIALTIES**

Loma Linda, California

## Orthopedists Appreciate These Features In Selby Junior Arch Preserver Shoes

**1** The spacious broad toe, broad heel base and ball tread.

**2** The slim back for snug quarter fitting and snug fitting of the arch.

**3** The ⅛″ wedge at inner border tapering to feather edge at outer border.

**4** The sturdy base on which inlays can be added when indicated by doctor.

**5** The soft, smooth, supple leather linings best suited for growing feet.

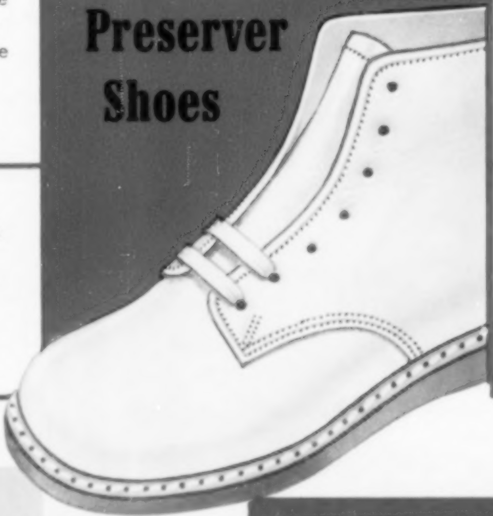
**6** The upper leathers of highest quality—light, strong and flexible.

**7** The insoles made of extra heavy leathers eliminate ridges and curling.

**8** The oak bend outsoles, Viscolized for resistance to moisture and wear.

**9** The back seams dog-ear reinforced for greater strength.

**10** Selby Junior Arch Preservers are smart and stylish in appearance.



*The only genuine Arch Preserver Shoes for children*

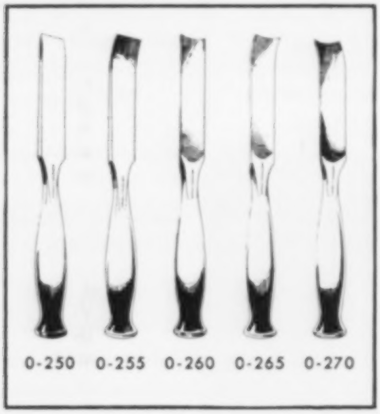
**Selby**
**JUNIOR ARCH PRESERVER**
**Shoes**

- *If Selby Junior Arch Preservers are not available in your city, please write directly to us.*

**The Selby Shoe Company**
*Portsmouth, Ohio*

MORE THAN THREE QUARTERS OF A CENTURY OF FINE SHOEMAKING

# SMITH-PETERSEN OSTEOTOMES and GOUGES



**0-250** SMITH-PETERSEN OSTEOTOME—straight, 8", sizes ¼", ⅜", ½", ⅝", ¾", 1" and 1¼". Stainless Steel.

**0-255** SMITH-PETERSEN OSTEOTOME—curved, 8", sizes ¼", ⅜", ½", ⅝", ¾", 1" and 1¼". Stainless Steel.

**0-260** SMITH-PETERSEN GOUGE—straight, 8", sizes ⅜", 9/16", ¾" and 1". Stainless Steel.

**0-265** SMITH-PETERSEN GOUGE—curved, 8", sizes ⅜", 9/16", ¾" and 1". Stainless Steel.

**0-270** SMITH-PETERSEN GOUGE—reverse curved, 8", sizes ⅜", 9/16", ¾" and 1". Stainless Steel.

## A NEW STAINLESS STEEL CASE TO HOLD SMITH-PETERSEN OSTEOTOMES and GOUGES

0-295 Open

**CASE 0-295**—holds seven Smith-Petersen Osteotomes.

**CASE 0-296**—holds seven Smith-Petersen Gouges.

**CASE 0-297**—holds a combination of seven Osteotomes and Gouges.

**Cutting edges are protected at all times.**
**Complete unit may be autoclaved.**

0-295 Closed

*Specify Width of Gouges and Osteotomes When Ordering*

CS
ESTABLISHED 1838

Codman & Shurtleff, Inc.
MAKERS OF SURGEONS' INSTRUMENTS
104 BROOKLINE AVENUE    BOSTON 15, MASSACHUSETTS

**VISIT OUR EXHIBIT—BOOTHS 28 & 29**
**American Academy of Orthopedic Surgeons—Jan. 28–Feb. 2**

The new ZOROC has everything!

*Plaster + Resin + Catalyst*
*. . . and it's all in the bandage*

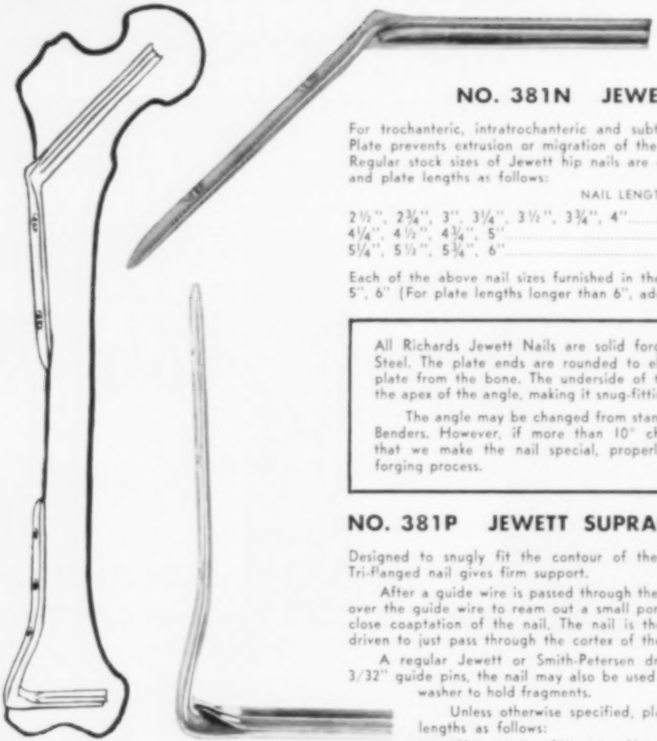
Just dip squeeze apply

ZOROC®
RESIN-PLASTER
BANDAGE
4" WIDE
Johnson & Johnson
THREE YARDS LONG

Johnson & Johnson

Richards

# JEWETT NAILS



## NO. 381N JEWETT HIP NAIL

For trochanteric, intratrochanteric and subtrochanteric fractures of the femur. Plate prevents extrusion or migration of the Smith-Petersen nail portion.
Regular stock sizes of Jewett hip nails are cannulated, angle of 135°, with nail and plate lengths as follows:

| NAIL LENGTHS | |
|---|---|
| 2½", 2¾", 3", 3¼", 3½", 3¾", 4" | **$12.50** each |
| 4¼", 4½", 4¾", 5" | **13.50** each |
| 5¼", 5½", 5¾", 6" | **14.50** each |

Each of the above nail sizes furnished in the following plate lengths: 2", 3", 4", 5", 6" (For plate lengths longer than 6", add $1.25 per inch).

All Richards Jewett Nails are solid forged of one piece SMO Stainless Steel. The plate ends are rounded to eliminate abrupt protrusion of the plate from the bone. The underside of the plate is curved completely to the apex of the angle, making it snug-fitting to the bone.

The angle may be changed from standard by using the No. 414 Jewett Benders. However, if more than 10° change is desired, we recommend that we make the nail special, properly forming the angle in our hot forging process.

## NO. 381P JEWETT SUPRACONDYLAR NAIL

Designed to snugly fit the contour of the condyles and shaft of the femur. Tri-flanged nail gives firm support.

After a guide wire is passed through the condyles, a ½" D. reamer is placed over the guide wire to ream out a small portion of the lateral cortex to provide close coaptation of the nail. The nail is then placed over the guide wire and driven to just pass through the cortex of the medial condyle.

A regular Jewett or Smith-Petersen driver may be used. Cannulated for 3/32" guide pins, the nail may also be used in conjunction with a tibia bolt and washer to hold fragments.

Unless otherwise specified, plate length of 6" furnished, with nail lengths as follows:

| | |
|---|---|
| 2", 2¼", 2½", 2¾", 3", 3¼", 3½", 3¾", 4" | **$17.50** |

## NO. 381S JEWETT SHOULDER NAIL

Indicated for fractures of the upper end of the humerus, mainly in the surgical neck area, or in fractures involving both the anatomical and the surgical neck in some instances.

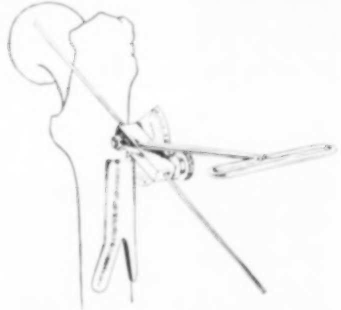
Also adaptable for rotation osteotomies in the upper end of the femur in the young patient. The nail is not long enough to go into the epiphysis of the head of the femur yet is long enough to give stability with the use of a plaster spica. Nail is removed following complete healing of the bone.

Reduced in all dimensions from regular Jewett Nail. Non-cannulated. Plate length 2"; nail lengths as follows:

| | |
|---|---|
| 1", 1¼", 1½", 1¾" | **$12.50** each |

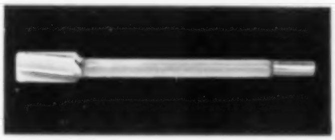
Richards MANUFACTURING CO., MEMPHIS, TENN.

# JEWETT NAIL INSTRUMENTS



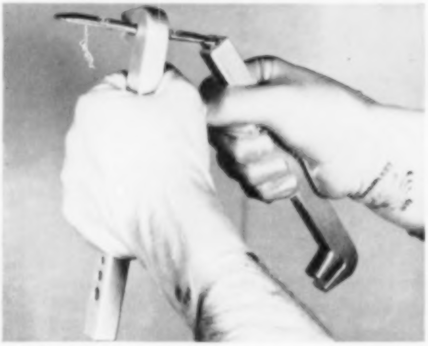
**NO. 381GA ADJUSTABLE JEWETT NAIL GUIDE** ............ **$25.00**

Stainless Steel. Adjustable with quick positive lock. Protractor reading instantly gives correct angle. Guide pin may be inserted and then its angle measured, or Guide may be used to give pre-determined angle to pin.



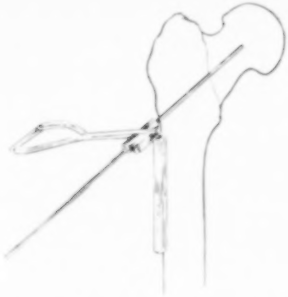
**NO. 381R REAMER** ............ **$12.00**

Cannulated, 1/2" diameter, stainless steel



**NO. 414 PAIR JEWETT BENDERS** ........ **$12.00**

Lightweight yet strong, made of heat treated aluminum alloy. Will not mar or nick SMO stainless bone plates. The nail end of the Jewett Nail is inserted into one end of the benders and the plate is gripped by the sturdy jaw of the other for bending. Also useful in bending and forming bone plates, intramedullary nails, and for twisting heavy plates.

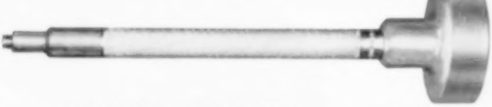


**NO. 381G JEWETT NAIL GUIDE** ........ **$10.00**

Non-adjustable. For use as a drill jig only, giving an exact angle of 135° to the guide wire. Stainless.

**NO. 381D DRIVER,** stainless ............ **$ 7.00**

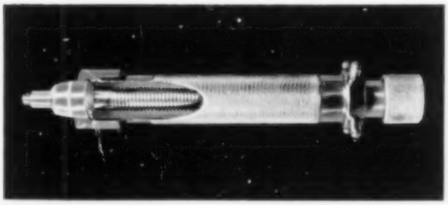
(Also fits Smith-Petersen Nails)



**NO. 381DK DRIVER** with Aluminum hand driving knob, stainless ............ **$10.00**

**NO.106A GUIDE PIN,** stainless
**$ .90** each ........ **$9.50** doz.

**NO. 106B GUIDE PIN,** Calibrated, stainless
**$1.25** each ........ **$14.00** doz.



**NO. 381E JEWETT NAIL EXTRACTOR,** stainless ............ **$25.00**

— *Richards* MANUFACTURING CO., MEMPHIS, TENN. —

# *You'll be glad to Prescribe...*

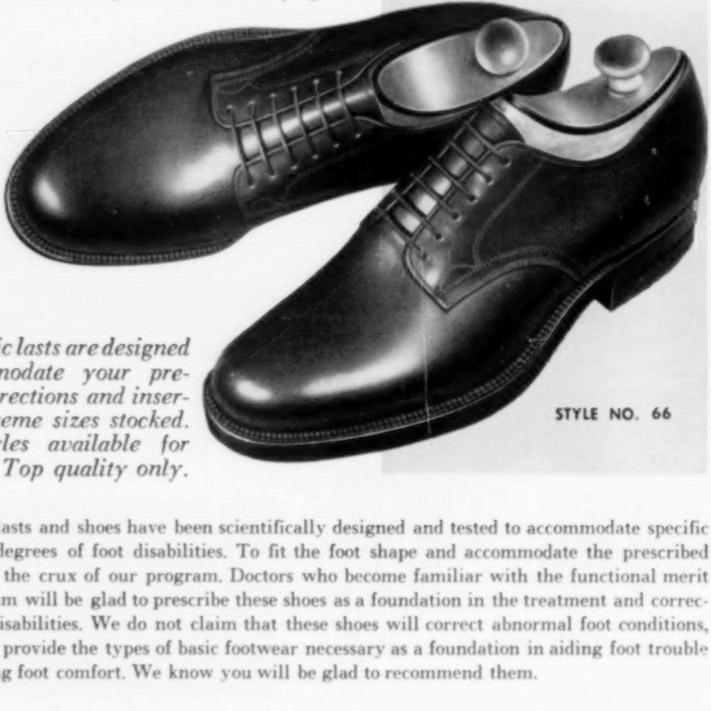
*Based on the most modern research program*

- Long inside counter
- Heavy gauge ribbed steel shank
- Right and left angled heels, long inside
- Patented bottom filler prevents insole lumping

**Alden-Pedic**

**SCIENTIFIC CONSTRUCTION**

**SHOES**



*Alden-Pedic lasts are designed to accommodate your prescribed corrections and insertions. Extreme sizes stocked. Many styles available for men, boys. Top quality only.*

Alden-Pedic lasts and shoes have been scientifically designed and tested to accommodate specific and general degrees of foot disabilities. To fit the foot shape and accommodate the prescribed corrections is the crux of our program. Doctors who become familiar with the functional merit of this program will be glad to prescribe these shoes as a foundation in the treatment and correction of foot disabilities. We do not claim that these shoes will correct abnormal foot conditions, but they will provide the types of basic footwear necessary as a foundation in aiding foot trouble and in offering foot comfort. We know you will be glad to recommend them.

**FOR BOOKLET AND NAME OF NEAREST DEALER, WRITE**

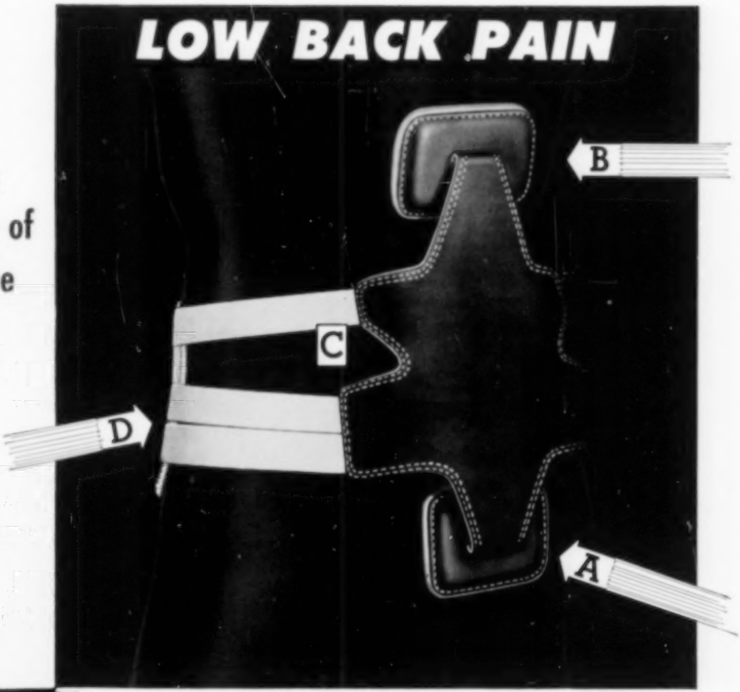
**C. H. ALDEN SHOE COMPANY**

**BROCKTON, MASS.**

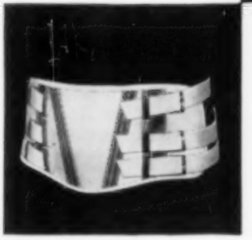
*Custom Bootmakers Since 1884*

# LOW BACK PAIN

## Announcing a New Principle of Relief with the Bell Posture Bridge by TRUFORM



Patented



*Eases facet impingement* in the lumbo-sacral area by means of entirely unique 3-point pressure. Observe in the photo these key features:

*Exerts Positive Forward Thrust* to tilt the pelvis, by direct contact of the lower pressure pad with the posterior surface of the sacrum. A

*Corrects Posture Defect,* even excessive lordotic lumbar curvature . . . with the upper pressure pad acting as a fulcrum. B

C *Makes No Other Contact* along the back, between the Bridge's two "piers" . . . there is no interference with the positive pressure of the two pads.

D *Applies Controlled Counter-Pressure* by means of the tightly-pulled straps.

"*Seeing Is Believing*" . . . so welcome the Truform fitter in your city, Doctor, when he calls to show you this new Bell Posture Bridge. Only by actually examining and applying this unique support can you fully appreciate its perfect adaptability to the relief of low back pain. Over 500 patients . . . with and without sciatic involvement . . . have already proven the Bell Posture Bridge during its development and clinical evaluation.

As with all Truform Anatomical Supports, this Bell Posture Bridge is

***"Available Only from Your Ethical Appliance Dealer"***

Write for "Truform Red Book," the fully illustrated reference catalog of Anatomically Correct Surgical Supports and Surgical Hosiery.

**®TRUFORM**

***anatomical supports***
3960 ROSSLYN DR., CINCINNATI 9, OHIO

®TRUFORM
The Professional Line
ANATOMICAL SUPPORTS

**Sabel's *Open Toe Pre-Walker Club Foot Shoe**

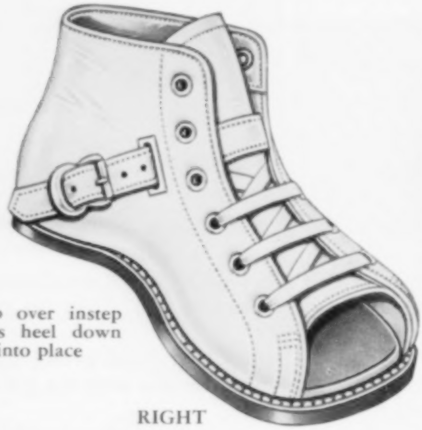
*for* INFANTS

SABEL'S CLUB FOOT SHOE
TRADE MARK REG. U.S. PAT. OFF.

*† This latest Pre-Walker Club Foot shoe will allow for closer fittings. It will enable you to see that the toes are in correct position, and that the heel is well down in the shoe.*

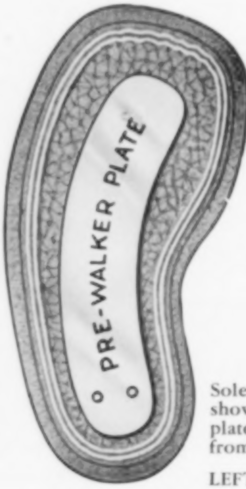
CARRIED IN STOCK

*The Pre-Walker Surgical shoe with OPEN TOE, the matching shoe where only one foot requires the Pre-Walker Club Foot shoe.*



Strap over instep holds heel down into place

RIGHT



Sole removed to show flat steel plate extending from heel to toe

LEFT

**THIS Pre-Walker Club Foot shoe is designed and made for infants to be worn until the child can stand or walk alone. The "PRE-WALKER" Club Foot shoe can be worn by the infant at all times, and also can be kept on while the child is in bed. Its function is to keep the foot in the exact position that the physician has obtained.**

**As the infant progresses to the point of walking or standing alone and further corrections are required, then the regulation Sabel Club Foot shoe can be used until the fixation desired has taken place.**

THE COMPLETE SABEL LINE WILL BE ON DISPLAY AT THE AMERICAN ACADEMY OF ORTHOPAEDIC SURGEONS CONVENTION, BOOTHS 67 AND 68, PALMER HOUSE, CHICAGO, JANUARY 28 THRU FEBRUARY 2, 1956.

I. SABEL, Inc.
1207 Chestnut Street Philadelphia 7, Pa.

BOOKLET WITH COMPLETE DETAILS ALSO DEALERS' NAMES UPON REQUEST

*Made Exclusively by*

THOMPSON BROS. SHOE CO., Brockton, Massachusetts

# now!

*for truly symmetrical sockets, use*

# CO-AXIAL SOCKET REAMERS

*with the detachable shank*

don't scrape . . . don't chisel . . . don't grind . . . don't try to improvise a truly symmetrical socket with instruments that *can't give you that result.*

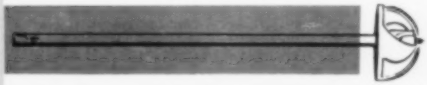
*Only*

## TOWER CO-AXIAL SOCKET REAMERS ARE CORRECTLY DESIGNED TO GIVE YOU

*Co-axial centering of shank • True symmetry • Precision cutting of cartilage, cortical and cancellous bone • Removal of cuttings • No clogging*

*All reamer sizes — 39, 41, 43, 45, 47, 49, 51, 53, 55 mm. diameter*

TECHNIC — Dislocate femur and displace posteriorally. Position reaming head in acetabulum — insert shank from below (through tissue and muscles along the normal femoral-neckline) and engage reaming head. After reaming is complete draw out shank and remove reaming head which retains cuttings.



*Since the reamer heads are available in a large range of sizes, please specify reamer diameter or mention the sizes of* **cups** *or* **prostheses** *with which they are to be used.*

SPECIAL GROUP PRICE
Any three reaming heads, plus detachable shank, plus brace — $175.00 complete.

**THE TOWER COMPANY, INC.**

SEATTLE
FRACTURE AND SURGICAL EQUIPMENT

P. O. Box 3181, Seattle 14, Washington
Fifth and Stevens, Geneva, Illinois

WHEN YOU GO
TO HER
RESCUE—

**Lynco**
TRADE MARK

Non-Metallic
Muscle-Building
Arch-Cushions

**Ashley**
TRADE MARK

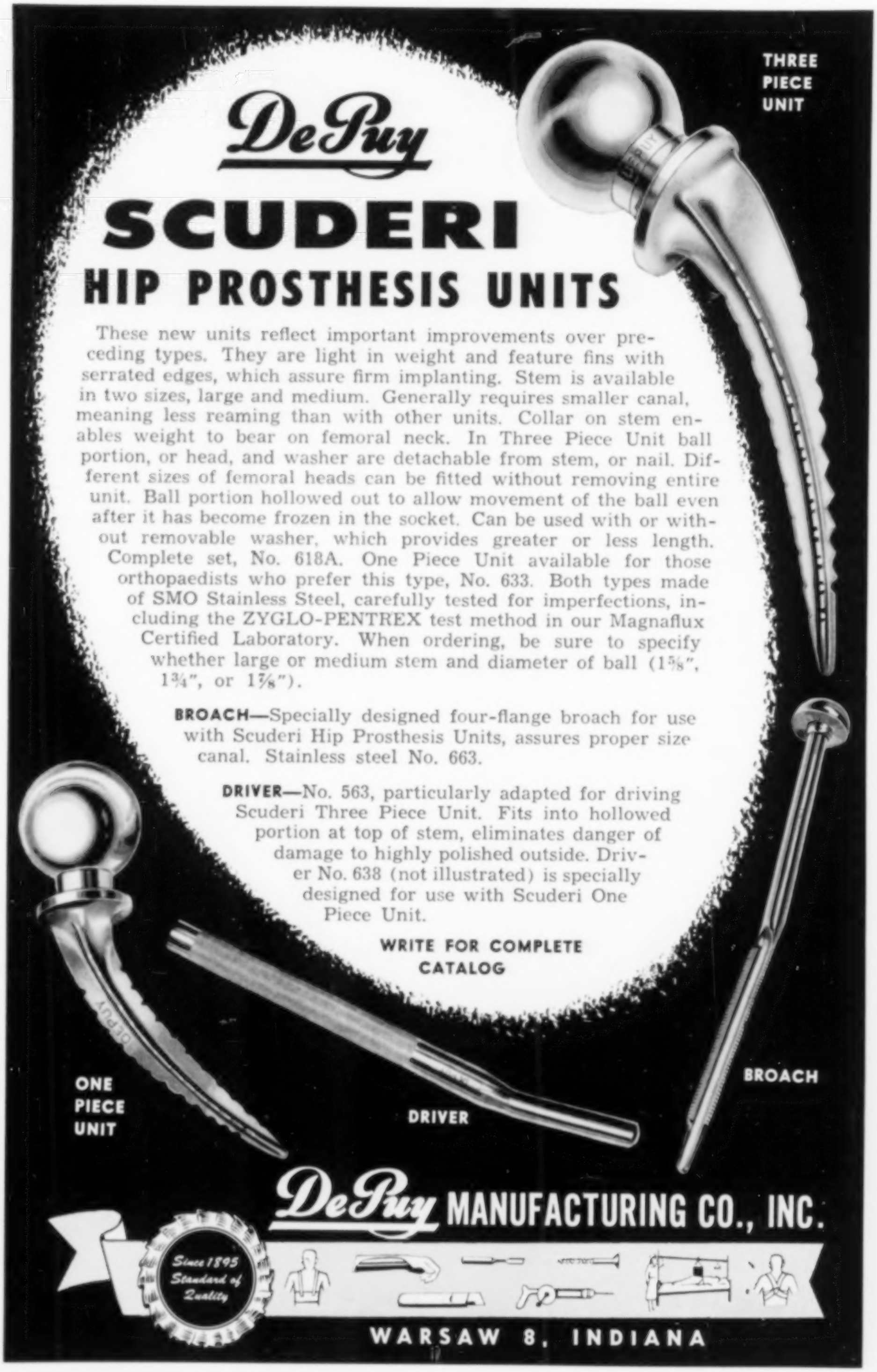
Posture Plates

YOU CAN RELY on KLEISTONE to fill exactly your prescriptions for orthopaedic appliances. Doctors depend on KLEISTONE's long experience, skilled technicians and modern laboratories to meet, with meticulous attention, the special requirements of prescriptions.

BOTH ready-made and custom-made pieces are fashioned from the highest quality materials. All orders are filled promptly. When you recommend orthopaedic appliances, be sure to recommend the very best . . . KLEISTONE.

*Write now for helpful, illustrated catalogs*

**KLEISTONE RUBBER COMPANY, Inc.**
Established 1919
**Warren, Rhode Island, U. S. A.**



DePuy

SCUDERI

HIP PROSTHESIS UNITS

These new units reflect important improvements over preceding types. They are light in weight and feature fins with serrated edges, which assure firm implanting. Stem is available in two sizes, large and medium. Generally requires smaller canal, meaning less reaming than with other units. Collar on stem enables weight to bear on femoral neck. In Three Piece Unit ball portion, or head, and washer are detachable from stem, or nail. Different sizes of femoral heads can be fitted without removing entire unit. Ball portion hollowed out to allow movement of the ball even after it has become frozen in the socket. Can be used with or without removable washer, which provides greater or less length. Complete set, No. 618A. One Piece Unit available for those orthopaedists who prefer this type, No. 633. Both types made of SMO Stainless Steel, carefully tested for imperfections, including the ZYGLO-PENTREX test method in our Magnaflux Certified Laboratory. When ordering, be sure to specify whether large or medium stem and diameter of ball (1⅝", 1¾", or 1⅞").

**BROACH**—Specially designed four-flange broach for use with Scuderi Hip Prosthesis Units, assures proper size canal. Stainless steel No. 663.

**DRIVER**—No. 563, particularly adapted for driving Scuderi Three Piece Unit. Fits into hollowed portion at top of stem, eliminates danger of damage to highly polished outside. Driver No. 638 (not illustrated) is specially designed for use with Scuderi One Piece Unit.

**WRITE FOR COMPLETE CATALOG**

DePuy MANUFACTURING CO., INC.

WARSAW 8, INDIANA

finer...faster service for your patients

With United States Pre-Fabricated brace parts, your Orthotist is able to fit your patients better and faster with parts that are interchangeable and easily replaceable. Specify United States pre-fabricated braces to be sure that your patients are equipped with the newest developments in orthopedic appliances.

Available in Crescent Orthopedic Steel or 24 S.T. Aluminum. French-Lock, Drop-Lock or Free-Lock Types.

QUALITY USMC

*We will be pleased to send you, upon request, a complete catalog of United States orthopedic appliances. Write to*

**UNITED STATES** *Manufacturing* **COMPANY**

*Manufacturers of pre-fabricated brace parts and orthopedic equipment*

**3453 Glendale Boulevard • Los Angeles 39, California**

| 1950 | 1952 | 1954 | 1955 |
|---|---|---|---|
| Cortone® | Hydrocortone® | 'Alflorone' | Deltra® |

the delta$_1$ analogue of hydrocortisone

# 'Hydeltra' tablets

(Prednisolone, Merck)

**5 mg.-2.5 mg.-1 mg.**

**(scored)**

**'Hydeltra'** **Indications:**

- RHEUMATOID ARTHRITIS
- BRONCHIAL ASTHMA
- INFLAMMATORY SKIN CONDITIONS

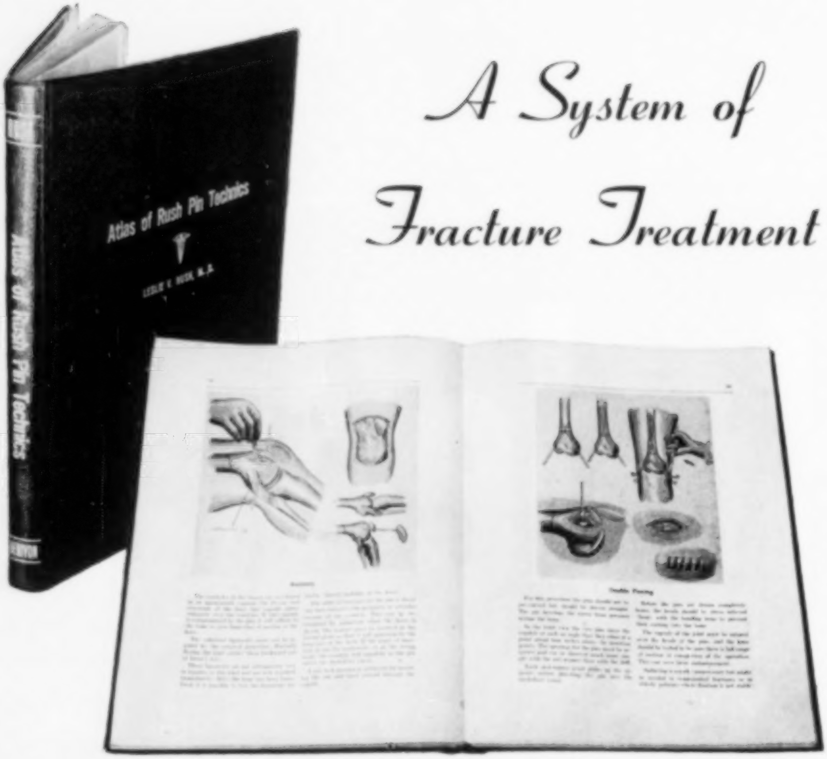
**'Hydeltra'** *offers increased clinical effectiveness . . . lowers the incidence of untoward hormonal effects.*

**'Hydeltra'** *is supplied as 2.5 mg. and 5 mg. scored tablets in bottles of 30 and 100.*

SHARP & DOHME
Philadelphia 1, Pa.
DIVISION OF MERCK & CO., INC.

*HYDELTRA is the trade-mark of Merck & Co., Inc. for its brand of prednisolone, supplied through Sharp & Dohme, Division of Merck & Co., Inc.*

*A System of Fracture Treatment*


Atlas of Rush Pin Technics
LESLIE V. RUSH, M.D.
Atlas of Rush Pin Technics
BERIVON

# ATLAS OF RUSH PIN TECHNICS

**by LESLIE V. RUSH, M.D.**

A new system of Dynamic Fracture Fixation • Precisely presented in Pictures with commentary • 227 Pages; 895 Illustrations • Printed on heaviest white enamel stock • Size 10 x 13 inches • Heavy deluxe binding of Maroon DuPont Fabricord • Section sewn to open flat • Hard rounded backs with head bands • Silk screen patches and 23 carat gold leaf lettering • Weight — 4 pounds.

*At your dealer's or direct*
*$15.00*

**THE BERIVON Company**
P. O. BOX 1851
Meridian, Miss.

# Now MELMAC® outmodes ordinary plaster

resin plaster of Paris

# BANDAGE makes stronger, lighter, water-resistant casts

**ready to use**
combines resin, plaster of Paris and catalyst in one bandage. Just dip in water

▲

**at last a water-resistant cast!** Yet it's stronger than ordinary plaster! New casts of MELMAC® resin plaster of Paris BANDAGE can be washed—resist urine and wound exudate—are porous to water vapor. Are little affected by humidity or body moisture. Do not become soft, weak and soggy in humid weather as do ordinary plaster casts.

**lighter, less fatiguing** shoulder spica of MELMAC BANDAGE. Encourages prescribed exercise. Shortens hospital stay. Makes care easier. Bandage for bandage, MELMAC BANDAGE has 2 to 4 times the strength of ordinary plaster—is self-mending in the early molding stage. Fashion these better plastic casts with fewer bandages. ▶

**Easy to apply and remove.** 1. Just dip MELMAC BANDAGE into tepid water for 5 to 10 seconds. Squeeze out excess water thoroughly. Apply. 2. Use about half the usual number of rolls (or less). 3. Dispose of waste the same as with ordinary plaster. There is less mess. 4. Remove the thin cast easily with cast cutter, knife or cast saw. Send for sample.

**Sensitivity:** Since this product may contain traces of formaldehyde, persons who are known to be sensitive to it should be observed closely for dermatitis. Operators using the bandage repeatedly should wear rubber gloves if skin sensitivity exists.

Patent Applied For

**Davis & Geck**

**MELMAC®**

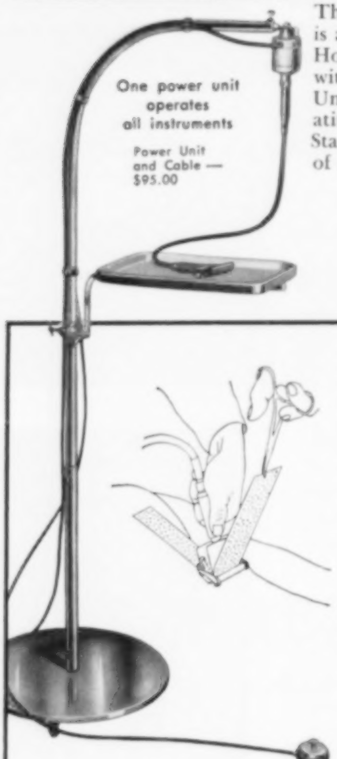
resin plaster of Paris **BANDAGE**

Davis & Geck, Inc., a unit of American Cyanamid Company, Danbury, Connecticut.
**Sutures and other surgical specialties**

**6 POWERED SURGICAL INSTRUMENTS AT THE SURGEON'S FINGER TIPS WITH Stryker Electro-Surgical Unit**

**One of a Series — THE STRYKER ROLO-DERMATOME**

The Stand and Mayo Table is a convenient accessory. Hospitals may assure compliance with National Board of Fire Underwriter Standards for operating room safety by using the Stand which guarantees mounting of the motor above 5 ft.



One power unit operates all instruments

Power Unit and Cable — $95.00

**Rolo-Dermatome $148.00**

Because of the small size and compact construction of the Dermatome, every desired graft site is completely accessible. The 35,000 cutting strokes per minute eliminates vibration and assures perfect control. Throw-away blades are easy to change.

Desired graft thickness is easily set by one simple lever – from 5/1000" to 30/1000". Maximum graft width is 3". Stationary parts contacted by blade are carboloy for long wear. Only two parts to clean.

Dermatome rolls, rather than slides, requiring no skin preparation. Stryker skin tape can be used if desired.

Stryker Rolo-Dermatome guaranteed for two years.

*Ask for the Stryker Rolo-Dermatome on approval — write today*

Rhinoplasty Saw-Seltzer $132.00

Depth Gauge and Drill Guide $12.00

Bone Drill Hand Piece $110.00

Bone Saw $98.00

Automatic Screwdriver $24.50

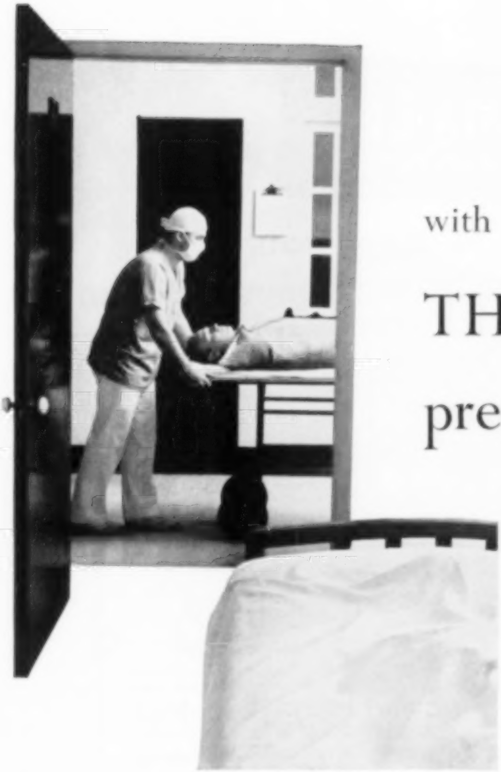
Color-Guide Drill Holder and Shield $28.00

Color-Guide Screw Case $25.00

*Write, wire or phone for a demonstration*

In Canada: Fisher and Burpe, Ltd.
Winnipeg, Manitoba

**Orthopedic FRAME COMPANY**
Kalamazoo Michigan



with

THORAZINE*

preoperatively—

"anxiety and apprehension

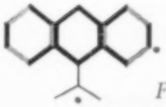
give way to

relaxation and calmness"[1]

When added to premedication, 'THORAZINE':

"(1) Augments the action of anesthetics so that reduced doses of these agents can be used to provide satisfactory anesthesia.
"(2) Decreases reflex irritability.
"(3) Markedly inhibits postoperative vomiting.
"(4) Reduces the need for postoperative narcotics and sedatives."[1]

1. Mathews, Morris and Moyer: Am. Pract. & Dig. Treat. 6:360 (Mar.) 1955.



'Thorazine' Hydrochloride is available in ampuls, tablets and syrup.

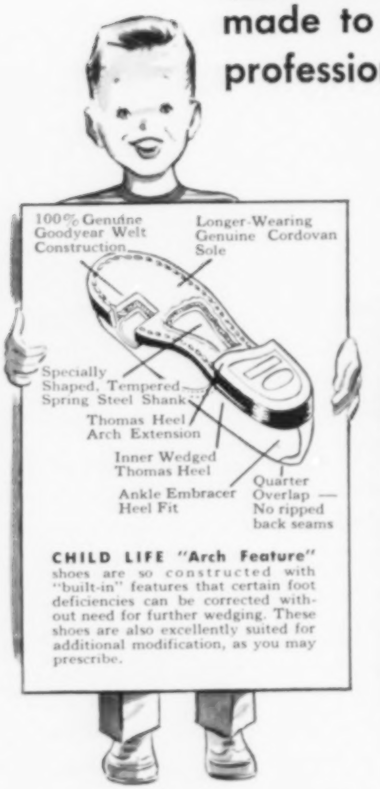
*For information write:*

*Smith, Kline & French Laboratories*
*1530 Spring Garden Street, Philadelphia 1*

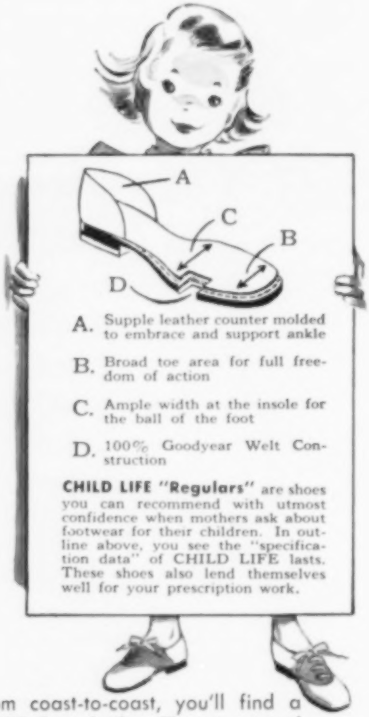
*T.M. Reg. U.S. Pat. Off. for chlorpromazine, S.K.F.

Child Life
SHOES

## made to merit your professional recommendation


100% Genuine Goodyear Welt Construction
Longer-Wearing Genuine Cordovan Sole
Specially Shaped, Tempered Spring Steel Shank
Thomas Heel Arch Extension
Inner Wedged Thomas Heel
Ankle Embracer Heel Fit
Quarter Overlap — No ripped back seams

**CHILD LIFE "Arch Feature"** shoes are so constructed with "built-in" features that certain foot deficiencies can be corrected without need for further wedging. These shoes are also excellently suited for additional modification, as you may prescribe.



A. Supple leather counter molded to embrace and support ankle

B. Broad toe area for full freedom of action

C. Ample width at the insole for the ball of the foot

D. 100% Goodyear Welt Construction

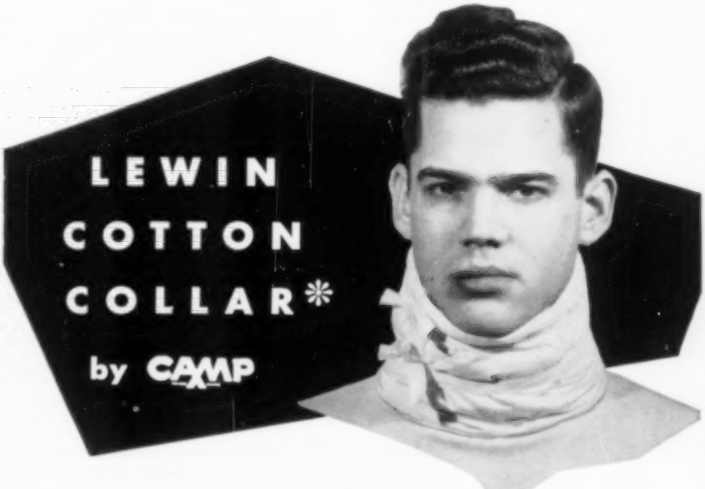
**CHILD LIFE "Regulars"** are shoes you can recommend with utmost confidence when mothers ask about footwear for their children. In outline above, you see the "specification data" of CHILD LIFE lasts. These shoes also lend themselves well for your prescription work.

In almost every community from coast-to-coast, you'll find a qualified and franchised CHILD LIFE shoe dealer. These men and women have been selected for their knowledge of good fitting practices, and for their specific interest in children's footwear. You'll find them most co-operative and attentive to your prescription work. Please write for full information on CHILD LIFE shoes — on the market since 1924 — and the names of the CHILD LIFE dealers nearest you.

**HERBST Shoe Manufacturing Company**

**Milwaukee 45, Wis.**

**simple, comfortable, effective**



**CAN BE USED IN CASES OF:** arthrities, fibrositis, brachial neuropathy, radiculitis, the neck-shoulder-hand syndrome, muscle injuries and subluxation of vertebral articular facets.

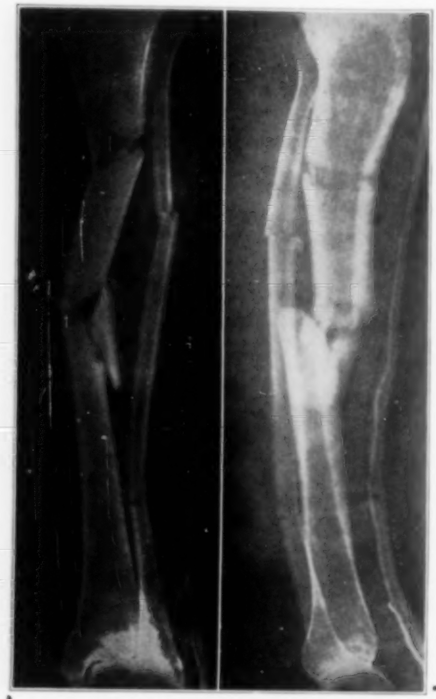
**HELPFUL IN:** taking X-rays in cases of acute injuries, in infections, exposure to cold and dampness, neurologic lesions, poliomyelitis, and post-operative care.

**HAS BEEN USED:** in cases of certain ear conditions, in cases where casts or braces were formerly used, in occipital neuritis and painful swallowing. The Lewin Cotton Collar has also been used in conjunction with the Jackson Pillow or head traction or with the Tractolator.

**SUPPORTS, PREVENTS FURTHER INJURY, PROTECTS AGAINST DRAFTS. HELPS RETAIN BODY HEAT, COMFORTABLE. CREATES MILD TRACTION, REMINDS PATIENT TO BE CAREFUL.**

** As described in THE JOURNAL OF THE AMERICAN MEDICAL ASSOCIATION, Vol. 155, No. 13, July 24, 1954.*

S. H. CAMP AND COMPANY, Jackson, Michigan
*World's Largest Manufacturers of Anatomical Supports*
OFFICES: 200 Madison Ave., New York; Merchandise Mart, Chicago
FACTORIES: Windsor, Ontario; London, England



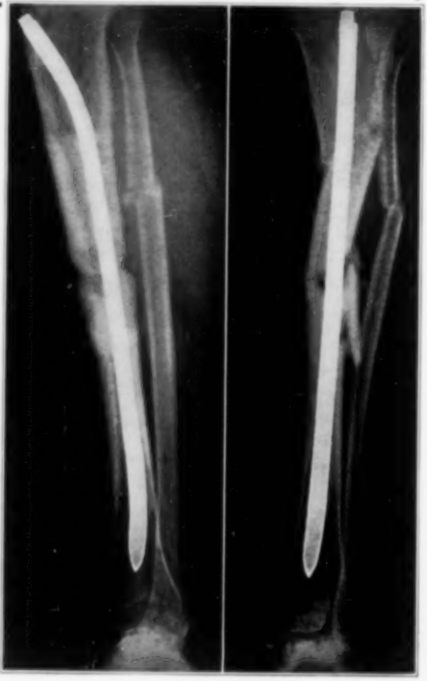
# LOTTES TIBIAL NAIL

LOTTES TRIFLANGE TIBIAL NAIL
Tibial Nail diameters: $\frac{5}{16}$'' and $\frac{3}{8}$''

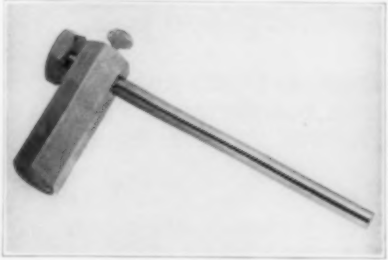
18-8 SMo Stainless Steel nail made in ½ inch lengths from 9 to 14½ inches.

The triflange nail is also available for femur, humerus, radius, and ulna.

COMPOUND FRACTURE WHICH WAS DEBRIDED, CLOSED, AND PLACED IN CAST ON ADMISSION ● RESULT THREE MONTHS AFTER PRIMARY HEALING OF WOUND AND CLOSED NAILING



The driver and extractor can be used with any of the triflange nails.



DRIVER AND EXTRACTOR

*For further information, please write to*

**CHAS. A. SCHMIDT SURG. INST. CO.**
**3689 Olive Street**
**ST. LOUIS 8, MISSOURI**

## OFFICE PATIENT... OR ...HOSPITAL PATIENT

**FOR MINOR WOUNDS,** TELFA *Strips* provide ample absorption with easy, painless removal. Five convenient sizes—and they can be cut to fit any wound. Fast, primary healing—lower cost.

**FOR MAJOR SURGERY,** TELFA *Sponge-Pads* provide maximum absorption, retentiveness and protection from trauma or contamination. Yet dressing lifts off easily—tissue, stitches are undisturbed.

# USE TELFA WHEREVER WOUNDS ARE DRESSED

## to speed healing, save dressing time

### For routine use on all wounds... absorbs without sticking, lifts off painlessly

Wounds that you now dress with gauze, or with sponges and pads, can be dressed *better* with TELFA—in half the time.

Better, because TELFA gives you fast, *primary* healing. With its perforated "plastic skin" that goes next to the wound, TELFA absorbs drainage without sticking and never interferes with *natural healing* because TELFA is inert, unmedicated—no grease to complicate later treatment. Removal is simple, painless and does not disturb tissue or stitches.

And you save time because, whether you use a small TELFA Strip or a TELFA Sponge-Pad, *one dressing is all you need.* Hospitals report dressing costs cut 18% to 41%.

TELFA is supplied in both forms to meet all wound needs. TELFA *Strips,* for simple, minor wounds—including a large size for plastic surgery; and TELFA *Sponge-Pads,* for all routine surgical wounds and even for drainage cases.

*This means that you can now employ the advanced* TELFA *technique throughout your dressings practice.*

TELFA Strips in 2" x 3" and 3" x 4" sterile envelopes; in 2½" x 4", 3" x 8" and 8" x 10" hospital cases. TELFA Sponge-Pads in 4" x 5" and 5" x 9" hospital cases.

**Curity**
REG. U.S. PAT. OFF.
**TELFA®**
NON-ADHERENT
STRIPS OR
SPONGE-PADS
**BAUER & BLACK**
DIVISION OF THE KENDALL CO., CHICAGO

# • The Clinical Approach to Prosthesis •

The Clinical Approach at the Woodrow Wilson Rehabilitation Center, Fisherville, Virginia, features the Clinical Team—the *Orthopedist*, the *Prosthetic Technician* (a HANGER Certified Prosthetist), the *Physical Therapist*, and the *Occupational Therapist* (for arm amputees only).

All amputee patients are examined by this Clinical Team with the complete medical history and other records at hand. During the examination the patient is analyzed as an individual case with his particular advantages and limitations evaluated in relation to the possible courses of treatment. For example, whether a particular stump or joint condition can be corrected with therapy, or with special prosthesis fitting and construction; if not, is further surgery desirable. Then a course of rehabilitation is prescribed by the Orthopedist, including the Physical (and Occupational for arm amputees) Therapy necessary, the type of Prosthesis to be worn, and other special treatment or training required.

Immediately the patient's treatment by the Center begins according to the Prescription. The patient receives pre-prosthetic therapy in which the stump is conditioned to provide the most efficient use of the Prosthesis. He is supervised and treated in baths, heat, exercise, etc., by therapists and nurses specially-trained for this work.

When the patient actually begins to wear the prosthesis, the Clinical Team again works closely together in the rehabilitation program. The Prosthesis itself has been fabricated according to the measurements and specifications taken by the Prosthetist member of the Clinical Team. Careful attention is now given to fitting adjustments, continued therapy, and training exercises, such as walking, sitting, steps, etc. Unusual problems are cause for a complete review and possible change of prescription. For arm amputees, Occupational Therapy now becomes important, and the amputee spends part of each day learning to use the Prosthesis and to live an independent life. Trained Therapists and nurses supervise the teaching of dexterity and manipulation through blocks, games, doorknobs, faucets, tools, etc.

Most patients are ready for discharge in about six weeks. Each must appear at the Clinic for a final Prosthetic Performance Check-out by the Clinical Team and Official release by the Orthopedist.

This is one of many such Centers throughout the country where HANGER Technicians function as integral members of the Clinical Team. Each is an ABC Certified Prosthetist, and trained in Team rehabilitation. Feel free to call on any HANGER office for service at any time.

• • • • • • • **Hanger** PROSTHESES • • • • • • •

*AVAILABLE AT AUTHORIZED FACILITIES IN THE FOLLOWING CITIES:*

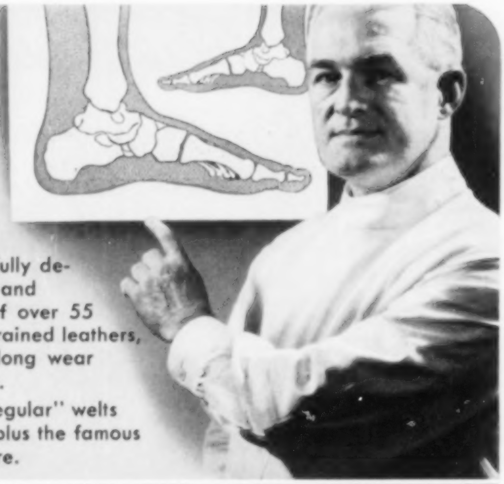
ATLANTA 1, GA.
BALTIMORE 1, MD.
BIRMINGHAM 1, ALA.
BOSTON 16, MASS.
CHARLESTON 2, W. VA.
CHARLOTTE 2, N. C.
CHICAGO 5, ILL.
CINCINNATI 2, OHIO
COLUMBIA 5, S. C.
COLUMBUS 8, OHIO
DALLAS 1, TEXAS
EVANSVILLE, IND.
INDIANAPOLIS 2, IND.
JACKSONVILLE, FLA.
KNOXVILLE, TENN.
MEMPHIS, TENN.
MIAMI 37, FLA.
MOBILE, ALA.
MONTGOMERY, ALA.
NASHVILLE, TENN.
NEW ORLEANS 19, LA.
NEW YORK 11, N. Y.
OKLAHOMA CITY 3, OKLA.
ORLANDO, FLA.
PHILADELPHIA 7, PA.
PITTSBURGH 30, PA.
RALEIGH, N. C.
RICHMOND 18, VA.
ROANOKE 12, VA.
ST. LOUIS 3, MO.
SHREVEPORT, LA.
TAMPA 2, FLA.
WASHINGTON 13, D. C.
WILKES-BARRE, PA.

# DOCTOR...

# Edwards

*THE SHOE FOR CHILDREN*

## AIDS YOUR EFFORTS



How? **Edwards** children's shoes are skillfully designed to meet your every prescription and recommendation. They are the result of over 55 years of craftsmanship. You'll find full-grained leathers, highest grade inner parts, proven fit, long wear and smart styling in every **Edwards** shoe.

A complete line—Todlins for infants, "regular" welts and cements and the "CorecTred" . . . plus the famous "Special" shoes shown here.

**SUPER-PEDIC**

for extreme cases of Pronation.

*(Above style available in Oxfords)*

**PRONA-PEDIC**

for extreme case of Supination.

*(Above style available in Oxfords)*

**PIGEON-TOE**

for mild cases of Supination.

*(Above style available in Oxfords)*

**STRAIGHT-LAST**

a basic shoe for corrections.

*(Above style available in Oxfords)*

**SURGICAL BOOT**

for Post - Operative fitting.

**CorecTred**

shoes with special fitting features.

The construction of the above Shoes maintains the longer wedge life demanded by your prescription. Recommend and prescribe **Edwards**.

May we send you several prescription pads and the name of your nearest **Edwards** retailer?

**Edwards**
THE SHOE FOR CHILDREN

***The Shoe for Children***
Philadelphia 7
Pennsylvania

# *Now available in English*

## The NEW EDITION of

# THE TREATMENT OF FRACTURES

## VOLUME I

**LORENZ BÖHLER, M.D.**

*Director of the Hospital for Accidents, Vienna, Professor of Surgery, University of Vienna*

*Translated from the 13th German Edition by* **Hans Tretter, Mrs. Lucchini, Frank Kreuz and Otto Russe**

*Covers Every Aspect in Meticulous Detail*

• fractures of the skull • mandible dislocations • spine fractures and dislocations • chest injuries • closed abdominal injuries caused by blunt force • open injuries to the abdomen • urinary system injuries • rectum injuries in pelvic fractures • impalement injuries • pelvic fractures • dislocation of the pelvis • clavicle fractures • clavicle dislocations at the sternal end • clavicle dislocations at the acromial end • gunshot fractures of the clavicle • fractures of the scapula • dislocations of the shoulder • abduction appliances • shoulder joint lacerations • fracture-dislocations of the humerus • gunshot wounds of the shoulder joint • fractures of the humerus • gunshot fractures of the humerus • elbow dislocations • rupture of the internal collateral ligament of the elbow • gunshot injuries of the elbow joint • fractures of the forearm • gunshot fractures of the forearm • dislocations of the lower radio-ulnar joint • dislocations of the wrist • fracture-dislocations of the semilunare • fractures of semilunare • malacia of the semilunare (Kienboeck's disease) • dislocations of the carpal scaphoid bone • fractures of the carpal scaphoid bone • fractures of other carpal bones • sprains of the wrist • gunshot wounds of the wrist • hand and finger injuries • closed dislocations of the 1st metacarpal • closed dislocations of the 2nd to 5th metacarpals • fractures of the metacarpals • dislocations of the finger joints • finger fractures • fresh open soft-tissue wounds of the fingers and hands • infected wounds of the fingers and hands •

For more than 26 years this monumental work has been considered as a standard reference for surgeons and orthopedists. Now, the new translation — based on the latest German edition — makes this revised, enlarged and completely up-to-date work accessible to every English-speaking physician. Stressing *techniques* of treatment throughout, this highly practical information has immediate application for office and clinic, and will provide an indispensable tool for day by day practice.

**1721 detailed illustrations.**

**Orders accepted only for the 3-volume set;**
**Volume II (May); Volume III (October).**
**Volume I $24.50.**

*Order Now, on approval*

Please send, on approval,

☐ **The Treatment of Fractures, Vol. I, $24.50**
(I will accept Volumes II and III on publication)

☐ **Check enclosed** ☐ **Charge my account**

Name.................................................................

Address.................................................................

JJ 156

**GRUNE & STRATTON, INC.**

381 Fourth Avenue
New York 16, N. Y.

NOW IN TWO POTENCIES

*for more precise dosage*

**NEW** 1 mg. pink tablet | 5 mg. tablet

MOST POTENT
ANTI-RHEUMATIC

**Sterane***

Both tablets are deep-scored and of the **SAME DISTINCTIVE "FINGER-GRIP" SIZE AND SHAPE** for ease of handling and breaking by arthritic fingers.

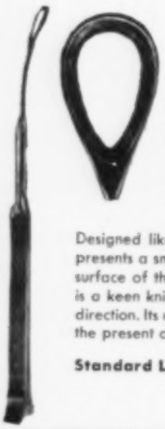
anti-rheumatic/anti-allergic/anti-inflammatory

**supplied:** **Pink,** 1 mg. oral tablets, bottles of 100.
**White,** 5 mg. oral tablets, bottles of 20 and 100.

**PFIZER LABORATORIES**
Division, Chas. Pfizer & Co., Inc.
Brooklyn 6, New York

*brand of prednisolone

# SAFER and QUICKER MENISECTOMIES with BOWEN Instruments



## Grover Menisectome

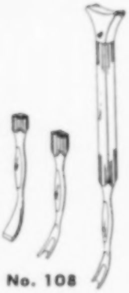
Used through any arthrotomy exposure and on either semilunar cartilage, it guarantees the integrity of all structures within the joint and permits complete removal of either meniscus.

Designed like a large intra-uterine curette, it presents a smooth rounded guard on the outer surface of the ring, the inner margin of which is a keen knife edge permitting cutting in any direction. Its use will shorten by about one-third the present operating time.

**Standard Length: 8½"** • **No. 128**

## Smillie Cartilage Sets

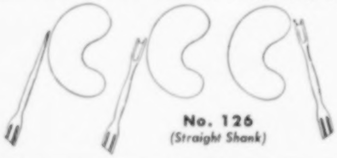
Designed with handles that do not obscure field of vision. Longer back always rests on tibial table. Beaked knife divides the peripheral attachments of the medial meniscus. Also divides the central attachment of the posterior horn of the lateral meniscus. Second beaked knife used for the same purpose, also to divide the central attachment of the posterior horn of the medial meniscus. Chisel mobilizes middle third of the meniscus.



**No. 108**

***(Curved Shank)***

**ILLUSTRATIONS SHOW POSITIONS OF KNIVES IN USE**



**No. 126**

***(Straight Shank)***

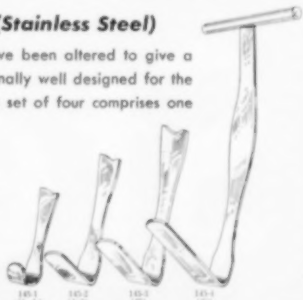
## Smillie Knee Joint Retractor Set *(Stainless Steel)*

The angles of the blades and the modified handles of these retractors have been altered to give a better grip and keep the fingers away from the incision. They are exceptionally well designed for the removal of menisci and for use in practically all knee joint operations. The set of four comprises one hook and three with blade lengths from 1½ inches to 3 inches.

**FEATURES:** "Sure grip handles for perfect control." • "Hardened and tempered to rigid specifications." • "Useful retractors for many other surgical procedures."

**No. 145 Knee Joint Retractor Set—$30.00**
(Four Pieces)

Priced Individually at $8.00 each



145-1 (Hook)

145-2 (1½")

145-3 (2")

145-4 (3")

*New!*

*Unique!*

## BOWEN Liquid DISPENSER

**For the dispensing of alcohol and other cleansing liquids.**

*Patent Applied For*

- *Quick Acting* • *Unbreakable* • *Will Not Tip*
- *Easily Operated with one hand*
- *To Use, Just Press on Metal Plate!*

**ONLY**
**$1.50**

**BOWEN & COMPANY, INC.**

P. O. BOX 5818
BETHESDA, MARYLAND

# now every surgeon can obtain "Gypsona"

## the world's most widely used plaster of Paris bandage

"Gypsona" bandages — long known as quality bandages — are now available to every physician in the United States. Originally developed in England, this bandage — made with a unique type of gypsum — has been used in every continent of the world.

To make "Gypsona" conveniently available in the U. S. A., plant capacity and distribution facilities in the States have recently been greatly expanded.

"Gypsona" is the hallmark of quality in plaster of Paris bandages because they are constructed from a specially woven gauze into which the unique gypsum is heavily, yet finely and evenly impregnated by a special process. "Gypsona" bandages contain just the right weight proportion of gypsum to cloth, to obtain, with fewer bandages, lighter yet exceedingly strong casts with a smooth, porcelain-like finish, and long wear.

True, "Gypsona" casts cost more per package but the superior functional performance effects an over-all economy.

That is the essence of quality achieved with . . .

Gypsona*

S&N

**SMITH & NEPHEW,** Inc., 137 East 25th St., New York 10, N. Y.

*Reg. Trade Mark of T. J. Smith & Nephew, Ltd., England

PLASTER OF PARIS BANDAGES

50 cc. Vial
(Pronounced Xī lo'cain)
XYLOCAINE®
HYDROCHLORIDE 1%
BRAND OF LIDOCAINE HYDROCHLORIDE
ASTRA PHARMACEUTICAL PRODUCTS, INC.
WORCESTER, MASS., U.S.A.

**. . . allow yourself the**

***greater versatility***

**of this dependable all-purpose local anesthetic**

Xylocaine is effective in low concentrations and in small volumes. It should not be used in more than half the concentration normally required of procaine for similar purposes. Because of the inherent potency of Xylocaine, depth and duration of anesthesia are adequate in such concentrations.

Supplied in concentrations of 0.5%, 1% and 2% with epinephrine 1:100,000 and without epinephrine. Dispensed 5 x 20 cc. and 5 x 50 cc. 1% concentration without epinephrine also dispensed in individually cartoned 100 cc. vials.

ASTRA PHARMACEUTICAL PRODUCTS, INC.
Neponset St. Worcester, Mass., U.S.A.

Also made and sold in Canada by
Astra Pharmaceuticals (Canada) Ltd.,
Toronto, Ontario, Canada

*U.S. Pat. No. 2,441,498
Can. Pat. No. 503,645

**Xylocaine® HCl**
(Pronounced Xī lo'cain)
**ASTRA**
(Brand of lidocaine* hydrochloride)

**for INFILTRATION • NERVE BLOCK • TOPICAL ANESTHESIA**

# The Journal of Bone and Joint Surgery

*The Official Publication of*
The American Orthopaedic Association
The British Orthopaedic Association
The American Academy of Orthopaedic Surgeons
The Australian Orthopaedic Association
The Canadian Orthopaedic Association
American Society for Surgery of the Hand
New Zealand Orthopaedic Association
South African Orthopaedic Association

JANUARY 1956

American Volume
Vol. 38-A, No. 1

8 THE FENWAY, BOSTON 15, MASSACHUSETTS, U. S. A.
BRITISH OFFICE:
82 PORTLAND PLACE, LONDON, W. 1, ENGLAND

# The Journal of Bone and Joint Surgery

PUBLISHED IN TWO VOLUMES

The Journal of Bone and Joint Surgery

AMERICAN VOLUME

*Editor*, and *Chairman* of the Board of Editors:
William A. Rogers

**American Board of Associate Editors**

David M. Bosworth, New York, N. Y.
Thornton Brown, Boston, Massachusetts
Edward L. Compere, Chicago, Illinois
Mark B. Coventry, Rochester, Minnesota
Harold E. Crowe, Los Angeles, California
G. W. N. Eggers, Galveston, Texas
David S. Grice, Boston, Massachusetts
Keene O. Haldeman, San Francisco, California
Charles H. Herndon, Cleveland, Ohio
Robert A. Knight, Memphis, Tennessee
Carroll B. Larson, Iowa City, Iowa
Michael L. Mason, Chicago, Illinois
John Royal Moore, Philadelphia, Pennsylvania
I. William Nachlas, Baltimore, Maryland
Fred C. Reynolds, St. Louis, Missouri
Robert A. Robinson, Baltimore, Maryland
Donald B. Slocum, Eugene, Oregon

The Journal of Bone and Joint Surgery

BRITISH VOLUME

Sir Reginald Watson-Jones, *Editor*

**British Editorial Board**

Professor Walter Mercer, *Chairman*
Philip Wiles, *Treasurer*
H. Jackson Burrows, *Deputy Editor*
J. Crawford Adams, *Assistant Editor*
J. M. P. Clark, Leeds, England
Alexander Gillies, Wellington, New Zealand
D. J. Glissan, Sydney, Australia
D. Ll. Griffiths, Manchester, England
A. R. Hamilton, Sydney, Australia
R. I. Harris, Toronto, Canada
A. J. Helfet, Cape Town, South Africa
F. W. Holdsworth, Sheffield, England
K. I. Nissen, London, England
H. Osmond-Clark, London, England
N. W. Roberts, Liverpool, England
J. Edouard Samson, Montreal, Canada
J. Trueta, Oxford, England
Denys Wainwright, Stoke, England

William A. Rogers, *Editor-in-Chief*

**Corresponding Editors**

*Argentina:* José Valls
*Austria:* Walther Ehalt
*Belgium:* Jean Verbrugge
*Brazil:* F. E. Godoy Moreira
*Cuba:* Alberto Inclán
*Denmark:* Johannes Mortens
*Finland:* K. E. Kallio
*France:* R. Merle d'Aubigné
*Germany:* Mathias Hackenbroch
*Italy:* O. Scaglietti
*Mexico:* Juan Farill
*Netherlands:* J. D. Mulder
*Poland:* Adam Gruca
*Portugal:* Arnaldo Rodo
*Sweden:* Sten Friberg
*Uruguay:* José Luis Bado

**Committees**

The Journal of Bone and Joint Surgery,
incorporated

***The American Orthopaedic Association***

***The American Academy of Orthopaedic Surgeons***

Board of Trustees

Robert W. Johnson, Jr., *Chairman*
Edward L. Compere, *Vice-Chairman*
Guy A. Caldwell, *Secretary*
David M. Bosworth, *Treasurer*
William A. Rogers, *Editor*
James S. Speed
H. Relton McCarroll

***American Society for Surgery of the Hand***

*President:* S. Benjamin Fowler
*President-Elect:* L. D. Howard
*Secretary-Treasurer:* George V. Webster
960 East Green Street, Pasadena 1, California

***The Australian Orthopaedic Association***

T. King, Melbourne, *President*
Warwick Stening, Sydney, *Editorial Secretary*
F. H. McC. Callow, *Secretary*, 141 Missenden Road,
Sydney, New South Wales

***The British Orthopaedic Association***

Philip Wiles, *President*
T. J. Fairbank, *Editorial Secretary*
J. I. P. James, *Secretary*
45 Lincoln's Inn Fields, London, W.C.2

***The Canadian Orthopaedic Association***

Alexander Gibson, Winnipeg
Robert I. Harris, Toronto
J. Edouard Samson, Montreal
F. P. Patterson, Vancouver
William B. MacKinnon, *Secretary*
661 Broadway, Winnipeg, Manitoba

***New Zealand Orthopaedic Association***

Morris Axford, Auckland, *President*
Harman Smith, Auckland, *Secretary*
Alan Alldred, Dunedin
J. K. Cunninghame, Wellington
N. Nisbet, *Editorial Secretary*
Dunedin Hospital, Dunedin C.1, New Zealand

***South African Orthopaedic Association***

C. T. Moller, *President*
W. T. Ross, *Treasurer*
Sidney Sacks, *Secretary*
1010 Medical Centre
Johannesburg, South Africa

Published in the United States by
The Journal of Bone and Joint
Surgery, Incorporated

Copyrighted in the United States by
The Journal of Bone and Joint
Surgery, Incorporated

Published in the United Kingdom for The British
Editorial Society of Bone & Joint Surgery Limited by
E. & S. Livingstone, Teviot Place, Edinburgh

Copyright in Britain and the Commonwealth by
The British Editorial Society of Bone &
Joint Surgery Limited

THE JOURNAL OF BONE AND JOINT SURGERY

*American Office*
8 The Fenway, Boston 15, Massachusetts, U.S.A.
*Managing Editor:* John A. Reed

*British Office*
82 Portland Place, London, W. 1, England
*Editorial Secretary:* Jean Barnes

VOL. 38-A, NO. 1 JANUARY 1956

The Journal of
Bone and Joint Surgery
*American Volume*

# RECURRENT DISLOCATION OF THE SHOULDER

## A Twenty-Four Year Study of the Johannesburg Stapling Operation *

BY G. T. DU TOIT, F.R.C.S. (ENG.), AND D. ROUX, JOHANNESBURG, SOUTH AFRICA

*From the Department of Orthopaedics, Witwatersrand University, Johannesburg*

The authors have reviewed 210 cases of recurrent dislocation of the shoulder treated by repair of the demonstrable lesion. In each case the detached labrum or the torn capsule was pinned to the rim of the glenoid cavity with staples and as far as possible nothing else was done at operation to alter the mechanics of the shoulder. Most of the operations in this series were performed by the authors themselves, but a few were performed by other members of the senior staff of the University general, industrial, and military hospital units (from 1930 onward).

In analyzing the results obtained in these cases, the authors discarded sixty cases because of inadequate records. In the remaining 150 cases, careful records and adequate follow-up had been maintained, and the available data was regarded as reliable.

Although recurrent dislocation of the shoulder can apparently be cured in a number of different ways, the search has been for a procedure which is based on a recognition of the pathological lesion and which restores the anatomy without inflicting positive damage.

### DEVELOPMENT OF THE STAPLING OPERATION

In South Africa the Bankart repair of a sheared-off fibrocartilaginous labrum[4,5] was first performed by F. P. Fouché and A. Lewer Allen. The technical difficulties found by these men in the use of the Bankart method gave rise to the idea of fixation by stapling. The first stapling operation was performed in 1931 by Fouché. In this operation he used chisel-pointed staples made of bicycle spokes and a piston-type introducer designed by Allen. The staples were driven in extra-articularly, pinning the capsule to the glenoid rim. Since 1931, the technique and instruments used in this operation have been perfected by minor modifications. Conical-pointed stainless-steel staples have been adopted because they show less tendency to twist out of alignment than do the chisel-pointed staples, and an improved staple introducer is now in use. Widening of the exposure by division of the coracoid process has been found to be redundant, and the worth of intra-articular stapling was tested and proved by A. D. Polonsky in 1931. As confidence in the stapling method has increased, speedier postoperative mobilization has been carried out. Our longest follow-up is that of a medical man treated by Polonsky in 1931.

Although the other procedures still have their adherents[1,13,15], the stapling operation has gained increasing support. It was demonstrated to Brig. H. Ogilvie during the War, and he published a report on it in 1946. Downing also referred to the stapling operation in 1946. Since that year, however, the idea seems to have elicited little attention in the literature.

---

* Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Los Angeles, California, February 2, 1955.

## ANATOMY

Attention should be directed to a few of the anatomical features of the shoulder joint. The oval articular surface of the glenoid cavity is shallow and is very small in proportion to the rounded, large articular surface of the humeral head. The concavity of the glenoid is increased substantially by the presence of a fibrocartilaginous labrum which forms a concentric, elastic cuff embracing the humeral head. This cuff adapts itself to the shape of the humeral head in all of its various positions and thus increases the stability of the joint. The shape of the labrum is crescentic, not triangular, in cross-section, and its fiber direction is concentric and longitudinal; scattered binding fibers are present. The labrum is attached to the rim of the glenoid by its inner border. This border blends with the cavity surface, while the periphery, being free and resilient, clings to the articular surface of the humerus like a suction cup. The shape of the antero-inferior portion of the labrum varies with the different positions of the arm. When the arm is adducted and internally rotated, this portion of the labrum relaxes and thickens; when the arm is abducted and externally rotated, this portion tightens and flattens. Although the labrum is thickest in this portion, its attachment is weakest at this point, and it is here that the typical lesion occurs. The capsule arises from the labroglenoidal attachment and sweeps medially over the neck of the scapula for a quarter-of-an-inch before being reflected off the bone. In this manner a furrow is formed between the labrum and the capsule. The normal joint capsule is so lax that in adduction it lies in loose folds inferiorly and could accommodate an object twice the size of the head of the humerus.

The inferior glenohumeral ligament is a thick band attached to the shaft of the humerus just below the lesser tuberosity. It attaches to the scapula by blending with the antero-inferior portion of the labrum near the scapular neck. Its superficial fibers become taut when the arm is externally rotated and abducted. It is a very strong structure and is functionally important in preventing forward dislocation during all manoeuvres of the shoulder. Between the inferior and middle glenohumeral ligaments, a subscapular recess of variable size is often present. The presence of this recess further weakens the attachment of the capsule to the labrum at this point.

Study of the musculature of the shoulder has demonstrated that the joint is adequately covered by muscle bellies and musculotendinous insertions. The weak spot in the shoulder lies between the medial aspect of the long head of the triceps and the lateral aspect of the humeral shaft. As the arm moves into abduction and external rotation, the muscles and tendons envelop the shoulder in a spiral fashion, thus effectively eliminating any circumferential instability. The labrum can be detached experimentally from the antero-inferior glenoid margin with comparative ease. The glenohumeral ligaments are more firmly anchored to the scapula than they are to the labrum.

## PATHOLOGY

In his original paper (1923)[3] Bankart maintained that the chief pathological feature in recurrent dislocation of the shoulder is the shearing-off of the capsule from the labrum. In 1938, however, he described the chief feature as being the separation of the fibrous labrum from its bony attachment[5]. Bankart found that there was no tendency whatever for a detached labrum to reattach itself to bone. Once the defect exists, it is permanent and thereafter the head of the humerus moves forward over the anterior margin of the glenoid on the slightest provocation. He found this lesion in twenty-seven consecutive cases and decided that it was an uncomplicated lesion demonstrable in every typical case of recurrent dislocation of the shoulder. He described how readily the head of the humerus can be pushed forward over the antero-inferior glenoidal margin once this

TABLE I

MECHANISM OF DISLOCATION

| Mechanism | Per cent |
|---|---|
| Sporting injuries | 43 |
| Injuries at work | 27 |
| Domestic accidents | 10 |
| Road accidents | 5 |
| Miscellaneous | 15 |
| | 100 |

lesion exists and suggested that reattachment of the labrum or of the capsule to bone was the rational line of treatment.

In the present series of 150 cases, only one patient did not show the typical pathological features. The pathological condition of three of the patients was inadequately reported at operation and so cannot be described here, but in the balance of the remaining 146 patients (that is, in 99 per cent) a clear-cut, easily recognizable Bankart lesion was present. In 11 per cent of these patients the bucket-handled labrum was excised in the same manner as a torn meniscus in the knee; in 21 per cent there was a well marked bare area on the antero-inferior aspect of the neck of the scapula, just medial to the glenoid margin; and in 10 per cent bony damage to the glenoid margin existed. In two patients the capsule was very thin and attenuated, and in 3 per cent there was a marked pouching of the capsule, which was exceptionally lax. Bony damage to the articular head of the humerus was found in 6 per cent, and a notch on the posterolateral aspect of the head of the humerus was demonstrated roentgenographically and at operation in 33 per cent. The presence of such a notch on the humeral head was first reported by Flower in 1861; since that time it has been reported frequently [6, 7, 14]. In a very few patients with a lesion of long duration, the torn labrum was fragmented and many residual tags were found; in one patient, the labrum was completely missing as the result of attrition; and in several patients small loose bodies were removed from the joint, these bodies apparently having been derived from the antero-inferior surface of the glenoid margin. In this series 95 per cent of the patients were under forty years of age; the changes that have been described are typical of acute traumata, not of normal degenerative processes. The evidence provided by this series confirms the already widely held view that the detachment of the labrum is the essential pathological feature in recurrent dislocation of the shoulder [6, 7, 9, 10, 20].

## DYNAMICS

Bankart stated categorically that the mechanism of the original dislocation in cases of recurrent dislocation of the shoulder is a fall backwards onto the shoulder or elbow [5]. Such a fall pushes the head of the humerus forward, causing it to shear off the labrum from the underlying bony glenoid margin. Many authors do not agree with Bankart on this point [1, 7]. In our series this mechanism was the cause in only 16 per cent of the cases, whereas in 65 per cent the original dislocation was due to falls onto the abducted and externally rotated arm (Table I). In 43 per cent of the cases the disability was due to a sporting injury, as in Rugby, football, horse-back riding, bicycle riding, and, occasionally, diving from a height. Of the patients who were injured at work, half were gold miners. If a miner, in going down an incline, loses his foothold, he attempts to save himself by grabbing hold of overhead timber. In this position his body weight forces the shoulder into hyperextension and abduction, and the latissimus dorsi and pectoralis major, with the help of the subscapularis, pulls the head of the humerus downward and forward. When the head slides forward, it pushes the labrum off the rim of the glenoid.

In patients with severe injuries, especially in muscular patients with severe trauma, the detachment of the labrum and the notching of the head by the hard edge of the glenoid usually occur at the time of the first dislocation. An associated minor fracture of the glenoid rim sometimes also occurs at this time. Later some new bone may form at the inferior capsular attachment of the glenoid. With further dislocations a secondary laxity of the capsule and ligaments may occur and also a wearing down of the labral edges, an increase in the irregularity of the notch, and an enlargement of the bare area on the neck of the glenoid cavity. When the sharp edge of the glenoid cavity engages in the notch on the posterosuperior surface of the humeral head, the glenoid rim becomes the fulcrum which allows the head to roll out into a subluxated position on the bare area in front of the glenoid. In a patient with a long-standing lesion the cul-de-sac into which the head dislocates may be lined with a thin adherent layer of scar tissue. This finding occurred in the three epileptics in the series.

The position of the glenoid cavity (facing downward laterally and forward), the advantage of the supraspinatus, infraspinatus, and teres minor over the subscapularis, and the relatively small size and shallowness of the glenoid cavity all combine to make the shoulder susceptible to dislocation in a forward and inferior direction. The advantage of the external rotators over the subscapularis is due partly to the shift during evolution of the insertion of the pectoralis minor from the greater tuberosity of the humerus to the coracoid process of the scapula (the more primitive insertion is still found in 17 per cent of Bantu patients). It is also partly due to the evolutionary torsion of the humerus, as described by Dickson, Humphries, and O'Dell.

In early Primates, the two tuberosities of the humerus were of equal size with the bicipital groove between them facing downward. "As the result of torsion, the bicipital groove has moved medially and has encroached upon the lesser tuberosity, thereby decreasing the rotatory potential of the scapularis. . . ." Although "the direction of pull of the supraspinatus is not perfect for external rotation power, [nevertheless] the mass of external rotators is at least equal to that of the subscapularis," and this circumstance, combined with the mechanical advantage of the external rotators, tends to roll the humerus outward. Operations designed to increase the rotatory potential of the subscapularis, such as, operations in which the subscapularis is transplanted laterally to the groove or in which the pectoralis minor is reinserted into the greater tuberosity, will also reduce the range of external rotation.

The surgeon rarely sees the patient at the time of the first occurrence of dislocation, so that the history usually is an important factor in diagnosis. Results obtained by physical examinations are frequently negative. Table II shows the features found in this series by the clinical examinations, and Table III shows the incidence of the recurrent dislocations.

## ROENTGENOGRAPHY

Roentgenograms assisted materially in confirming preoperatively the pathological features present in these patients. A notch was demonstrated in 12 per cent of the patients, humeral-head damage in 7 per cent, new-bone formation in the inferior margin of the glenoid in 4 per cent, and some irregularity of the outline of the glenoid in 15 per cent. In a few patients, dislocation of the acromioclavicular joint was shown to coexist.

## ARTHROGRAPHY

Arthrography was done in only a few cases in this series. When it was done, the technique described by Nelson was followed. The difficulties of interpreting shoulder arthrograms are considerable. Sometimes in this series of cases it was possible to demonstrate a pouching of opaque material in the position of the Bankart lesion, but even in these cases the findings did not materially influence the surgeon in his decision as to the appropriate treatment.

TABLE II

CLINICAL FEATURES

| | Per cent |
|---|---|
| Slight limitation of external rotation | 13 |
| Slight limitation of abduction | 13 |
| Abnormal passive anteroposterior mobility | 19 |
| Minor damage to the supraspinatus | 3 |
| Crepitation in the subacromial bursa | 2 |
| Crepitation in the main joint | 7 |
| Evidence of minor peripheral nerve injury | 1 |

TABLE III

INCIDENCE OF RECURRENT DISLOCATIONS

| | Per cent |
|---|---|
| In males | 93 |
| In females | 7 |
| Bilateral dislocations | 5 |
| Less than twenty dislocations | 50 |
| Less than five dislocations | 33 |

## OPERATIVE TECHNIQUE

The operation is performed as follows: With the patient supine, a medium-sized sandbag is placed under the upper portions of the chest in such a way that the vertebral border of the scapula on the affected side is pushed forward. The table is tilted to make the shoulder the highest point in order to minimize hemorrhage, and the shoulder is draped so that the arm may be freely moved. Through the deltopectoral approach the cephalic vein is retracted laterally with the deltoid, and the areolar tissue lying on the subscapularis is separated by blunt dissection. The coracobrachialis and the biceps are retracted medially, and the humerus is rotated externally. This exposes a considerable part of the subscapularis. The subscapularis is then split along the line of its fibers, from its bony insertion medially, for a distance of three inches. This split is deepened with a blunt instrument, and two retractors are inserted in order to expose the capsule of the joint. The capsule falls into loose folds as the degree of the external rotation of the arm is lessened, and when the arm is in neutral position, the lower anterior portion of the capsule is absolutely slack. After exposure, the capsule is opened along the same line as

TABLE IV

PERIOD OF FOLLOW-UP

| Number of Years | Number of Cases |
|---|---|
| Twenty-four years (Figs. 8-A and 8-B) | 1 |
| About twenty years | 2 |
| Nine years | 3 |
| Eight years | 8 |
| Seven years | 6 |
| Six years | 4 |
| Five years | 5 |
| Four years | 7 |
| Three years | 7 |
| Two years | 14 |
| One year | 90 |

was the subscapularis. This exposes the head of the humerus, the cleft of the joint, the anterior margin of the glenoid, and the lesion of the labrum (Fig. 1). Sometimes, the bare area on the anterior aspect of the glenoid is also demonstrated.

Through the incision the joint is easily inspected. If necessary, the head of the humerus can be dislocated through the split, the notch on its posterior aspect being thus exposed. After such a dislocation the muscles are very relaxed, which makes it easier to carry on further manoeuvres. The capsular margins with the synovial membrane are

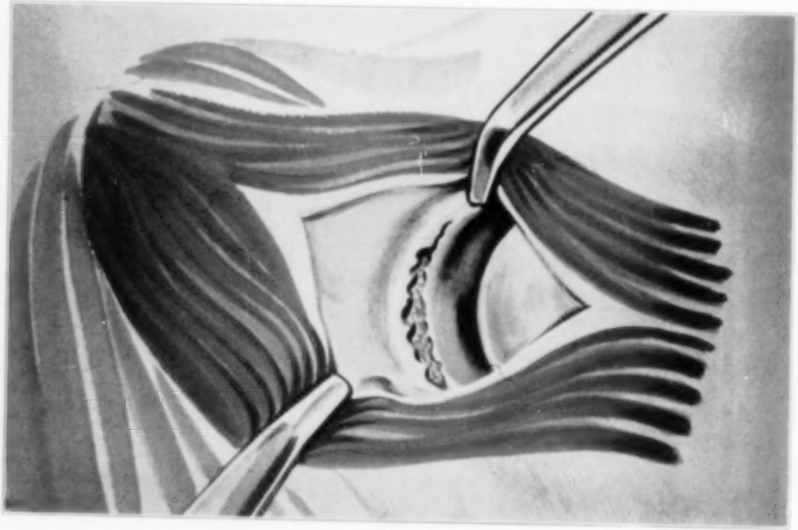


FIG. 1

The subscapularis has been split along the line of its fibers, and the capsule has been divided in the same plane. The lesion of the detached labrum is thus demonstrated, and bare bone is exposed in the depths of the fissure.

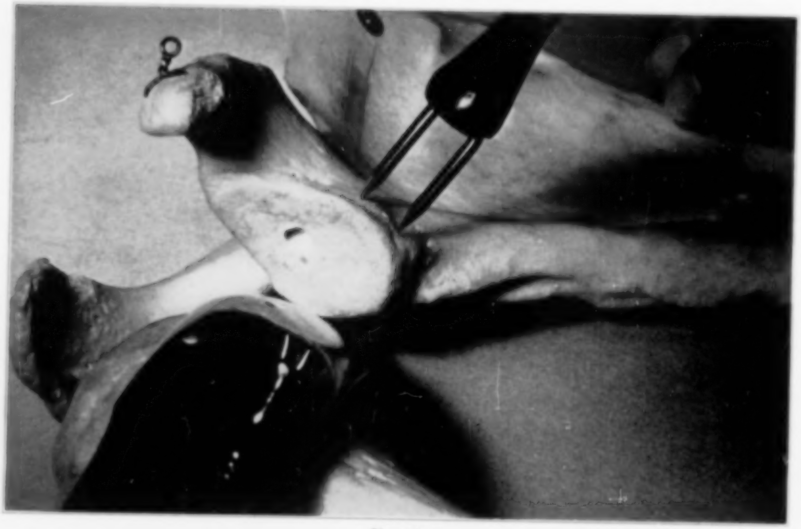


FIG. 2

This photograph shows the operation being demonstrated on a skeleton. The Bankart skid has been introduced into the joint, and its serrated toe is caught on the posterior margin of the glenoid. The serrations of the toe prevent slipping.

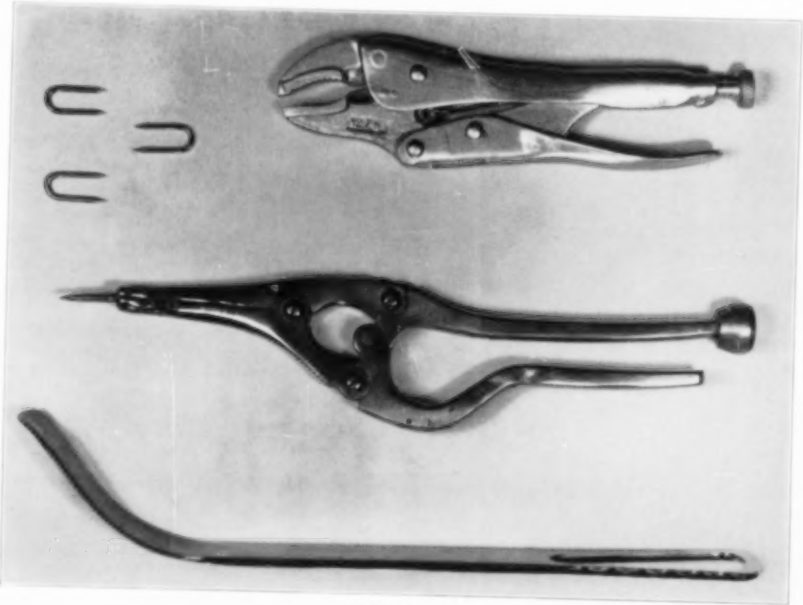


FIG. 3

*Top left.* These 14-gauge staples are one and one-eighth inches in length, and there is three-eighths of an inch between their points. *Top right.* This pair of vise-grip pliers may be used in place of the regular staple introducer, although it is not quite as convenient. *Center.* A staple is locked firmly in the milled jaws of the staple introducer. Its position is correct for insertion. *Bottom.* The Bankart skid is shown. When this skid is used correctly, the concave surface faces the head of the humerus, and the serrated toe rests on the posterior margin of the glenoid cavity.

retracted with vulsellum forceps, and a Bankart skid is inserted into the joint. The correct use of the Bankart skid is not generally appreciated. It should be inserted into the joint with the concave surface resting on the head of the humerus and the serrated toe thrust through the joint cavity so that it catches or impinges on the posterior margin of the glenoid, thus acting as a fulcrum for levering the head of the humerus backward (Fig. 2). When the skid is in place, the whole glenoid surface including the tear of the labrum can be readily demonstrated, and the best position for the staples can then be easily determined. The exposure provided by the skid is so complete that it is possible to place the staples intra-articularly or extra-articularly, whichever the operator prefers.

It is customary to use two staples; occasionally, however, one staple is sufficient, and exceptionally, with very extensive tears, three staples may be used. A self-locking staple-holder, working on the principle of the Payr clamp, has been found the most efficient means of inserting the staples (Fig. 3). If the labrum is bucket-handled, it is excised and the free margin of the capsule is firmly stapled to the margin of the bony glenoid. If the labrum is only detached, the staple is inserted just medial to the margin of the glenoid, transfixing the labrum and sometimes a fold of the capsule. It is driven deeply into the hard bone of the neck of the glenoid in such a way that it does not penetrate the articular surface but nevertheless its points are about a third of an inch beneath the cartilage (Fig. 4).

When the retractors and the Bankart skid have been removed, the edges of the capsule and of the split in the muscle fall together. The joint capsule is closed by continuous suture, but the muscles do not require repair; in fact, suturing the muscles may only do harm. The wound is closed in layers according to the surgeon's preference. In the majority of the earlier cases, the subscapularis was divided half an inch from the insertion, and the

TABLE V

ASSESSMENT OF RESULTS

| | Per cent |
|---|---|
| Postal questionnaire replies received | 93 |
| Cases re-examined and re-x-rayed | 55 |
| Expressed satisfaction with operation | 84 |
| Known resumption of original occupation | 90 |
| Known resumption of sport | 66 |

TABLE VI

FINAL LIMITATION OF MOTION

| | Per cent |
|---|---|
| Marked | 2 |
| Moderate | 2 |
| Slight | 23 |
| None | 68 |

joint capsule was freely opened along the same line, after which the stapling was carried out as already described. It is only in recent years that the subscapularis has been split rather than divided. This approach was suggested by Maxwell; and it has been found that it ensures more rapid convalescence and a quicker return to normal activities. On the third day after the operation, the large dressing is exchanged for a small patch dressing, and the patient is encouraged to use his hand, forearm, elbow, and shoulder. Circumduction movements, such as are used in polishing a table, are encouraged, and relaxed circumduction and pendulum swinging movements are carried out freely within the limits of tolerance. By the end of the week the shoulder joints of patients treated by this method have a very considerable range of motion, and after two weeks many have full range of motion (Figs. 5-A, 5-B, and 5-C). There need be no fear of allowing the patient to resume

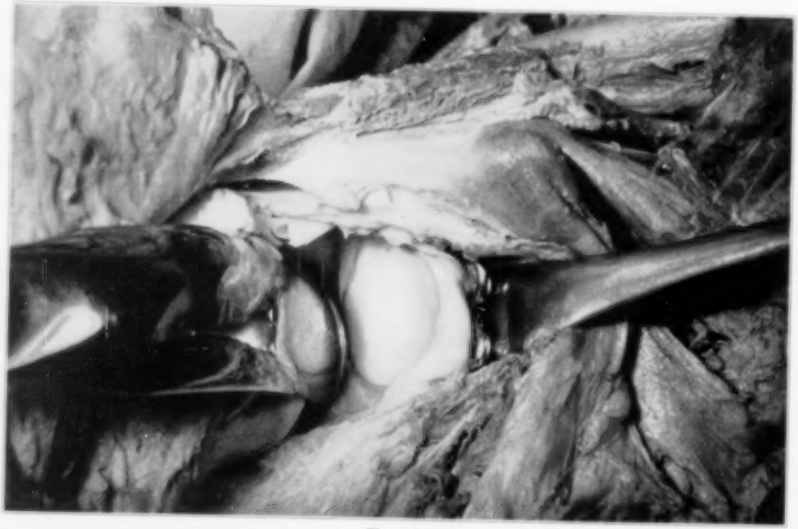


FIG. 4

*Left.* Two staples have been introduced. They have been driven in far enough to firmly attach the labrum to bone but not far enough to cause ischaemia in the transfixed tissues. The tops of the staples may protrude as much as a quarter of an inch. *Right.* The coracobrachialis and biceps are held back with a blunt retractor.

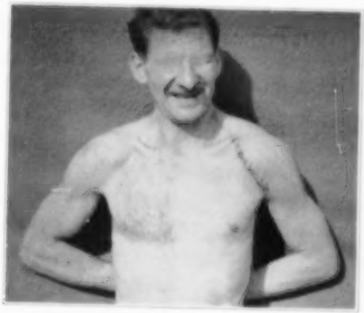


FIG. 5-A

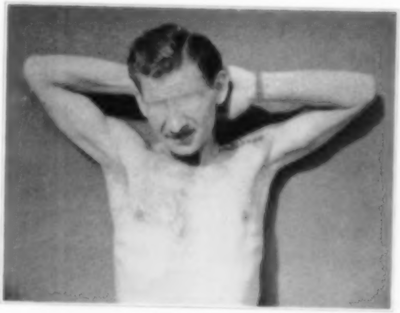


FIG. 5-B

Fig. 5-A: Six days after the operation there is full internal rotation.

Fig. 5-B: There is full external rotation six days after the operation.

Fig. 5-C: There is almost full abduction six days after the operation.

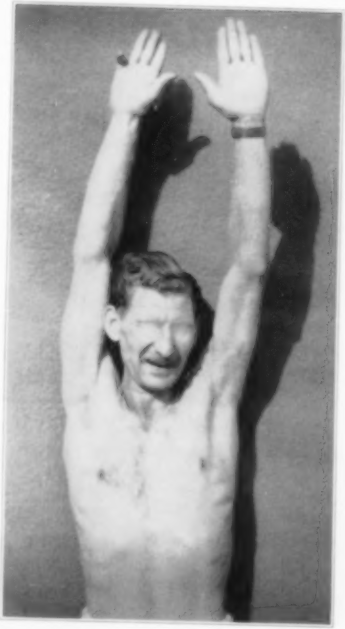


FIG. 5-C

work as soon as the stitches have been removed.

## RESULTS

Dickson, Humphries, and O'Dell in their recent book on recurrent dislocation of the shoulder stated that the general consensus of opinion is that some limitation of external rotation is essential in the cure of habitual dislocation of the shoulder. In the light of our experience with the stapling operation, this general opinion no longer seems justified. The stapling operation does not restrict external rotation at all and yet effects a cure in the majority of patients upon whom it is performed, as the end-results in this series show (Tables IV, V, VI, and VII).

The criteria adopted in assessing the results of 150 cases were as follows: The result was classed as *excellent* if there was complete recovery from the operation, with no recurrence of dislocation, no limitation of shoulder motion, no pain, and no roentgenographic evidence of disturbance in the position of the staples (Fig. 6). The result was considered *good* if there was slight limitation of motion instead of no limitation; and it was considered *fair* if there was no recurrence of dislocation, but there was a residual sense of weakness or instability or the staples caused a little mechanical trouble. This category included patients in whom the staples were wrongly used or were broken or in whom the necessity for the removal of the staples had arisen (Fig. 7). After further operations, the functional result in these patients was usually satisfactory. A *bad* result included recurrence of the dislocation, marked limitation of motion, the presence of disabling pain, and the occurrence of sepsis with permanent ill-effect.

In this series of cases, there were seven failures. One of these occurred because only one staple had been used, which was not adequate, and a cure was effected by the insertion of an additional staple. A second cure was effected by the plication of the capsule and the subscapularis by the Putti-Platt technique, and a third was effected by the repetition of the stapling operation in a more accurate manner. One shoulder dislocated postoperatively on one occasion and then not again. These four failures were due to technical causes. Of the remaining three patients in whom failure occurred, one suffered from epilepsy and had gross abnormal mobility of the shoulder. (In the other two epileptics recurrences did not develop.) In another, congenital abnormal mobility of the shoulder caused the operation to be a failure, and in the third the musculocutaneous nerve had been damaged when a hemostatic suture had been passed through it in an attempt to stop brisk hemorrhage. In this patient the twitching of the muscle drew attention to the error, and the suture was removed. Postoperatively the biceps and coracobrachialis were found to be paralyzed, but the patient made a complete recovery without any further treatment.

In one patient trivial sepsis occurred, and in another there was chronic low-grade sepsis, which resulted in complete destruction of the articular surface of the humerus as

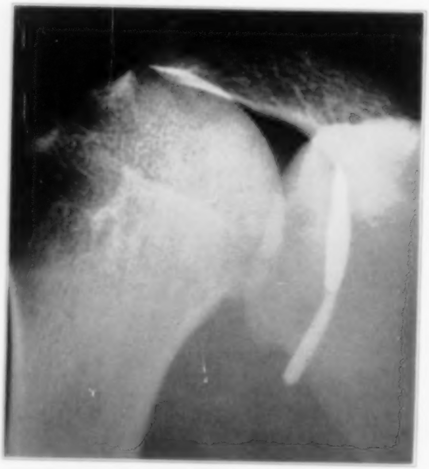


Fig. 6

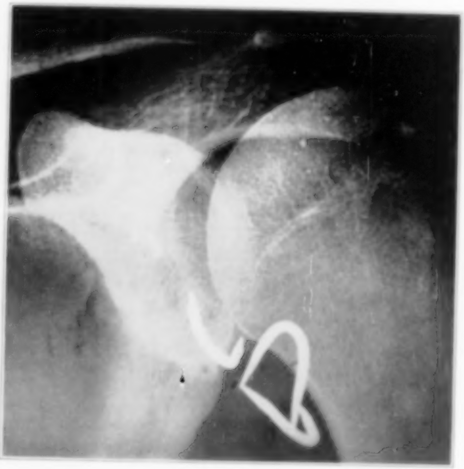


Fig. 7

Fig. 6: This anteroposterior view shows two staples in good position.

Fig. 7: This roentgenogram of a shoulder shows broken, displaced, and wrongly inserted staples, illustrating the dangers of using staples indiscriminately.

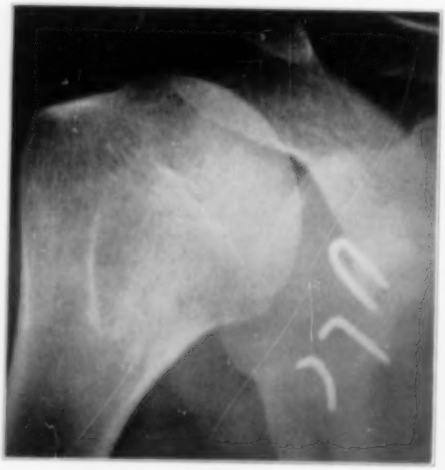


Fig. 8-A

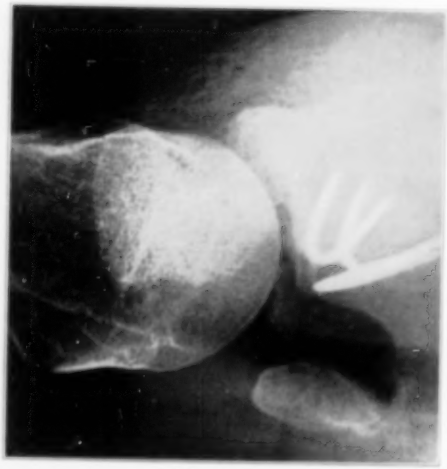


Fig. 8-B

Fig. 8-A: This roentgenogram was made twenty-four years after the operation. In this shoulder there is full range of motion and no disability. The result is good.

Fig. 8-B: This roentgenogram is an axial view of the same patient twenty-four years after the operation. There is no evidence of any degenerative change in the joint; the staples are still in excellent position; and the reaction around the staples is negligible.

well as of the glenoid. In spite of this serious complication, however, the man today has a shoulder which moves through two-thirds of the normal range of motion, and he is taking part normally in sports, such as cricket and tennis, and is working as a mining engineer.

In 3 per cent of the patients, the insertion of the staples was extracapsular while in the rest it was intracapsular. In 76 per cent more than one staple was used, but in 24 per cent one staple was sufficient to cure the condition. In 33 per cent, particularly in the earlier cases in the series, the coracoid was divided and subsequently reattached by fixation with another staple or by suture.

## PERIOD OF DISABILITY

The average period out of work for these 150 patients has been forty-three days. Some of the patients in the earlier series were out of work for substantially longer periods, but in recent years the period has been steadily decreasing, and in the most recent cases the period out of work has usually been not more than two weeks. The introduction of the muscle-splitting operation has been a definite factor in this reduction of the period of disability, but further study is necessary to determine exactly how great an improvement this procedure has been.

Assessments for Workmen's Compensation in South Africa are done according to a Government schedule which offers 10 per cent for the loss of the index finger and 42.5 per cent for the loss of a hand at the wrist. The average assessment for the Workmen's Compensation cases in this series was 7.3 per cent.

## CONCLUSIONS

1. In traumatic recurrent dislocation of the shoulder, a diagnosis of the Bankart lesion may be given with confidence and the operation planned accordingly.
2. The unsatisfactory results that sometimes occur after the stapling operation appear to be due to technical failure or to lack of judgement in diagnosing the lesion.
3. In cases of congenital abnormal mobility of the shoulder, the stapling operation is not the best procedure to use.
4. Where the Bankart lesion is present, the cure may be achieved by repairing the lesion only. There is almost never any need for additional procedures such as overlapping of the capsule, plication, or suspension.
5. Permanent disability is minimal after this procedure because no anatomical damage need be done.
6. Complications are rare, and no serious complications arising out of the use of staples were found in this series.
7. The remote prognosis for the patients in this series appears to be satisfactory.
8. The stapling operation has been found a simple and efficient alternative to the original dental drilling and suture of the Bankart operation.

## REFERENCES

1. Adams, J. C.: Recurrent Dislocation of the Shoulder. J. Bone and Joint Surg., **39-B:** 26–38, Feb. 1948.
2. Allen, A. L.: Personal communication.
3. Bankart, A. S. B.: Recurrent or Habitual Dislocation of the Shoulder-Joint. British Med. J., **2:** 1132–1133, 1923.
4. Bankart, A. S. B.: Dislocation of Shoulder-Joint. *In* Robert Jones Birthday Volume, pp. 307–314. London, Oxford University Press, 1928.
5. Bankart, A. S. B.: The Pathology and Treatment of Recurrent Dislocation of the Shoulder-Joint. British J. Surg., **26:** 23–29, 1938.
6. Bost, F. C., and Inman, V. T.: The Pathological Changes in Recurrent Dislocation of the Shoulder. A Report of Bankart's Operative Procedure. J. Bone and Joint Surg., **24:** 595–613, July 1942.
7. Dickson, J. A.; Humphries, A. W.; and O'Dell, H. W.: Recurrent Dislocation of the Shoulder, pp. 35–36, 43, 126, 139–143. Baltimore, The Williams and Wilkins Co., 1953.

8. Downing, F. H.: A Simplification of Bankart's Capsulorrhaphy for Recurrent Dislocation of the Shoulder. J. Bone and Joint Surg., **28:** 250–252, Apr. 1946.
9. Eyre-Brook, A. L.: The Morbid Anatomy of a Case of Recurrent Dislocation of the Shoulder. British J. Surg., **30:** 32–37, 1942.
10. Eyre-Brook, A. L.: Recurrent Dislocation of the Shoulder. Lesions Discovered in Seventeen Cases, Surgery Employed, and Intermediate Report on Results. J. Bone and Joint Surg., **30-B:** 39–46, Feb. 1948.
11. Flower, W. H.: On the pathological changes produced in the shoulder joint by traumatic dislocation, as derived from an examination of all the specimens illustrating this injury in the Museums of London. Trans. Pathol. Soc., London, **12:** 179–200, 1860–1861.
12. Fouché, F. P.: Personal communication.
13. Henderson, M. S.: Results Following Tenosuspension Operations for Habitual Dislocation of the Shoulder. J. Bone and Joint Surg., **17:** 978–983, Oct. 1935.
14. Hill, H. A., and Sachs, M. D.: The Grooved Defect of the Humeral Head. A Frequently Unrecognized Complication of Dislocations of the Shoulder Joint. Radiology, **35:** 690–700, 1940.
15. Magnuson, P. B., and Stack, J. K.: Recurrent Dislocation of the Shoulder. J. Am. Med. Assn., **123:** 889–892, 1943.
16. Maxwell, J. S.: Staple Introducer for Recurrent Shoulder Dislocation. British Med. J., **1:** 588, 1946.
17. Nelson, D. H.: Arthrography of the Shoulder. British J. Radiol., **25:** 134–140, 1952.
18. Ogilvie, Heneage: Recurrent Dislocation of the Shoulder. The Johannesburg Staple Driver. British Med. J., **1:** 362, 1946.
19. Polonsky, A. D.: Personal communication.
20. Townley, C. O.: The Capsular Mechanism in Recurrent Dislocation of the Shoulder. J. Bone and Joint Surg., **32-A:** 370–380, Apr. 1950.

# COMBINED HIP FUSION AND SUBTROCHANTERIC OSTEOTOMY ALLOWING EARLY AMBULATION *

BY FREDERICK R. THOMPSON, M.D., NEW YORK, N. Y.

*From the Orthopaedic Service of St. Luke's Hospital, New York*

The benefit resulting from hip fusion is well known. In the treatment of a painful, osteo-arthritic hip, this operation is still the procedure of choice, if one desires a stable, painless hip which will allow the worker to return to long hours of duty. The great disadvantages of the operation have been the magnitude of the surgery involved, the high incidence of pseudarthrosis [3], the resulting stiff knee, and, finally, the expensive months of bed rest in a double hip spica which have been considered necessary in the past in order that union might be secured in a proper, predetermined position. The procedure to be described was developed to overcome some of these disadvantages and to enable the patient to be ambulatory at an early date. A previous report of the results in seventeen patients treated by this method was made before the orthopaedic section of the New York Academy of Medicine in November 1949, at a joint meeting with the Philadelphia Orthopaedic Club.

Since Farkas, in 1939, first described the employment of subtrochanteric osteotomy in the fusion of a tuberculous hip, its use in the treatment of tuberculosis has been reported by other authors [2]. Patients so treated have needed to be kept in bed for long periods of time and have usually been immobilized in a bilateral hip spica in order that slipping at the osteotomy site might be avoided. The osteotomy has not been employed generally to stimulate fusion in non-tuberculous hips nor has it been employed to hasten fusion. The purpose of the subtrochanteric osteotomy in the author's procedure is to keep the long lever arm of the femur from causing motion at the site of the intended fusion. It is not generally realized that after hip fusion the femur, with the center of the head acting as a fulcrum, has a lever action of 23 to 1, the shaft being about thirty-five centimeters and the radius of the head being about 1.5 centimeters (Fig. 1). This 23-to-1 lever action makes minor thigh movements in the plaster of considerable significance. If the knee is fully extended, the lever action may be as much as 55 to 1. The osteotomy prevents this forceful lever from acting on the fusion site during the first postoperative weeks. The lever action probably does not begin to operate again until the fragments at the osteotomy site have united, which takes place about seven weeks after the operation.

## OPERATIVE TECHNIQUE

In January 1946, we began occasionally combining the subtrochanteric osteotomy with primary fusion, applying a single hip spica after the operation in order to permit early ambulation. We hoped that this operation would promote more rapid consolidation without causing undue complications. Most of the arthrodeses were of the intra-articular type (Fig. 12).

Ten arthrodeses were done without removal of the articular cartilage (Fig. 5) in order to decrease the magnitude of the surgery in some of the elderly patients; the flexion-adduction deformities present in these patients were corrected by means of the subtrochanteric osteotomy (Fig. 8). The technique employed in these operations was essentially the same as the one commonly used by us in similar fusions. A section of bone, consisting of both cortices and measuring two inches in length by an inch and a quarter in width, was cut from the anterior wing of the ilium (Fig. 2). A slot was then cut in the superior surface of the head and neck of the femur and in the adjacent ilium; this slot extended across the acetabulum and hip joint. The iliac bone graft was firmly wedged in the channel cut in the head and neck and was driven into place in the iliac slot so that in some instances it penetrated far into the bone. Additional chips were placed just posterior to the graft, where they were held loosely in place by the resutured gluteal muscles. In a few patients the graft, instead of being placed superiorly in the head and neck and driven into the ilium, was placed anteriorly and somewhat medially in such a way that it would be compressed if the hip should tend to move into the usual flexion-adduction position during the subsequent months. The osteotomy of the femur was performed by retracting the soft tissues distally and by severing the femur at the level of the lesser trochanter. This procedure provided relatively secure immobilization of the upper femoral fragment, but instances of angulation into coxa vara after its use have been reported[2]. The technique was not so secure a method of immobilization as we believed at the time.

---

* Read at the Annual Meeting of The American Orthopaedic Association, White Sulphur Springs, West Virginia, June 22, 1955.

In three patients Vitallium nails were driven across the joint line to immobilize the proximal fragment. A straight Smith-Petersen nail was used in one of these patients and a curved Warren White nail in a second (Fig. 6). In one patient the nail was driven in without removal of the articular cartilage and without insertion of additional chips or grafts (Fig. 7); failure was the result. This type of nailing procedure has a limited application and the outcome as to solid fusion is usually doubtful. In the third patient, a Smith-Petersen nail was combined with an onlay graft which was screwed into place. This use of the nail, combined with an intra-articular fusion, in our opinion is justified.

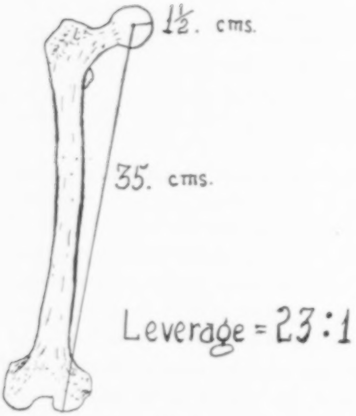


FIG. 1

Fig. 1: In hip fusion a subtrochanteric osteotomy eliminates the leverage action of the femur. This leverage action is normally about 23 to 1 but may be as much as 55 to 1.

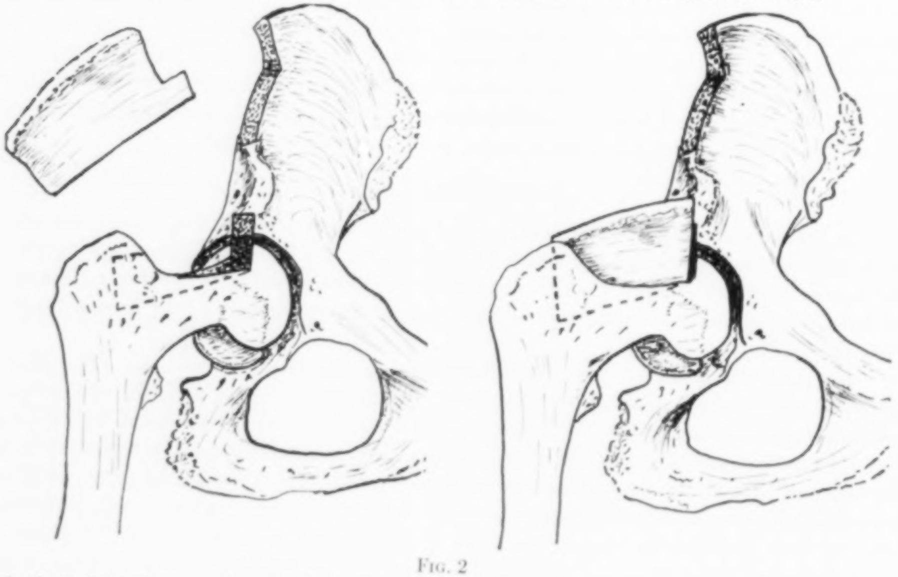


FIG. 2

In the earlier fusion operations, an iliac graft was impacted into a slot cut in the neck and head of the femur and in the adjacent ilium.

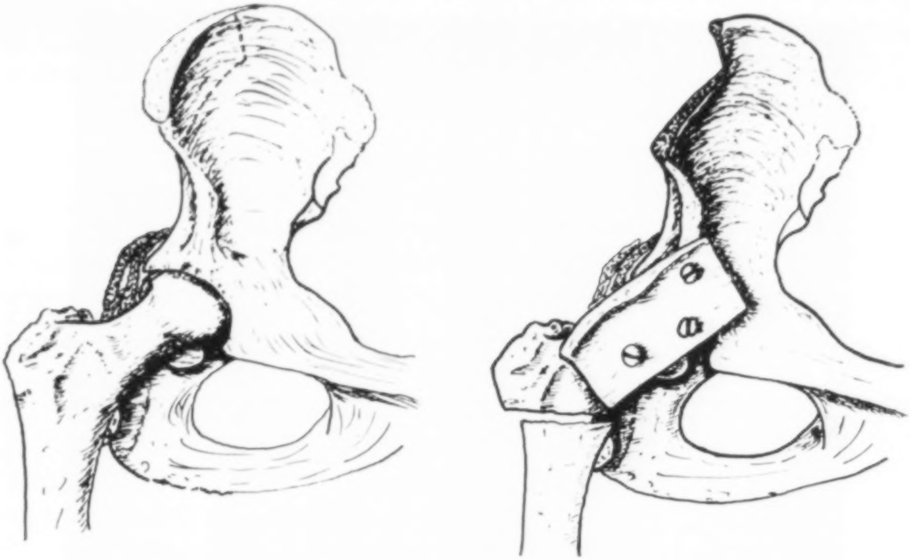


Fig. 3

In the present fusion operation, iliac chips are placed superolaterally in such a way that they will show in silhouette on the roentgenogram. An iliac graft is then screwed to the ilium and femoral head, and an osteotomy is performed to eliminate the lever action of the femoral shaft.

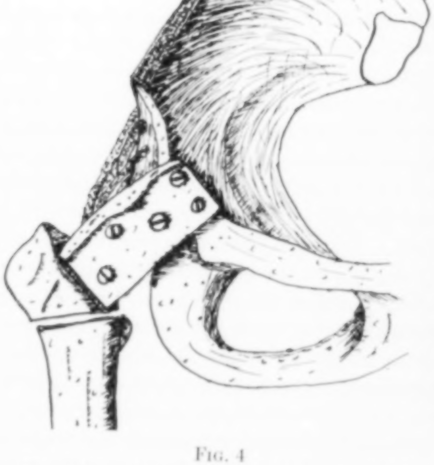


Fig. 4

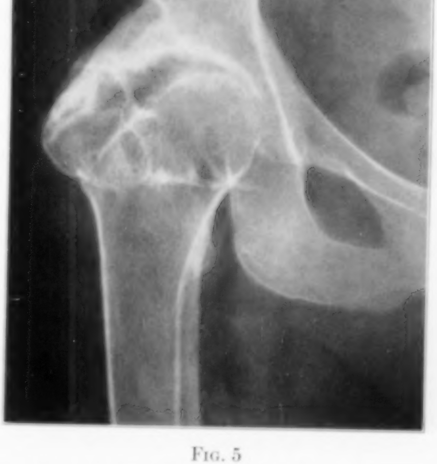


Fig. 5

Fig. 4: To obtain secure immobilization of the upper femoral fragment, five screws have been used to fix the graft to the ilium and femoral head and neck. The roentgenographic appearance of the bone chips placed superolaterally indicates the degree of solidarity attained at the osteotomy site.

Fig. 5: A roentgenogram made one year after the operation. The articular cartilage was not removed at the operation, but a graft was inserted. The fragments at the osteotomy site have united, and the fusion of the hip is solid, although it does not extend throughout the joint.

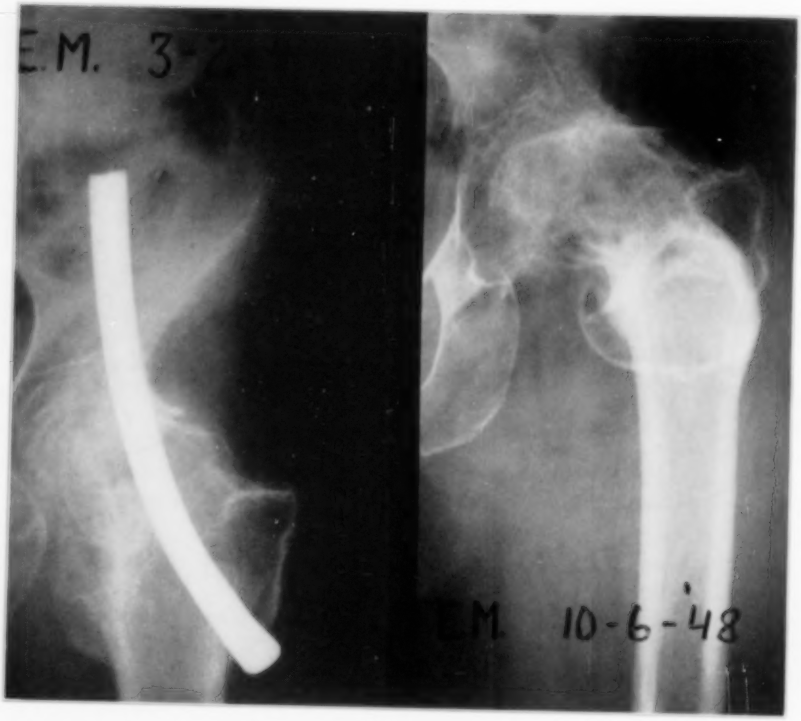


Fig. 6

After removal of the articular cartilage and performance of an osteotomy, a curved Warren White nail was used to immobilize the proximal fragment. The roentgenogram on the right, made seven months after the operation, shows that the nail has been removed, the fragments at the osteotomy site have united, and solid fusion of the hip has been obtained. It was very difficult to extract the nail.

Fourteen fusions have subsequently been performed by the following technique, which is still being employed. Through a Smith-Petersen incision a large, broad iliac graft, consisting of both cortices, is taken from the anterior two and one-half inches of the iliac wing and crest (Fig. 3). The rectus origin is freed and the muscle is retracted medially in order that good exposure of the anterior aspect of the hip joint and pubic ramus may be obtained. After the femoral head has been dislocated and the articular cartilage has been removed from the head and acetabulum, the graft is laid flatly against the anterior surface of the pubic ramus and against the head and neck of the femur, extending as far distally in some instances as the intertrochanteric line. In order that the graft may make even contact with this broad surface, it is necessary to remove the antero-inferior iliac spine, to shave off minor promontories on the pubic ramus, and to cut off a part of the anterior curve of the femoral head. The graft then makes good contact throughout its extent. Additional chips are taken from the ilium and are placed along the superior surface of the femoral neck so that they make contact with the wing of the ilium (Fig. 11). These grafts are an important addition since they show well in silhouette on the roentgenograms and their appearance as to consolidation on subsequent roentgenograms demonstrates the degree of solidity of the fusion. It is difficult to tell in early roentgenograms whether the large anterior graft has fused.

The onlay iliac graft is screwed into place. In our earlier cases we used three screws only. The upper screw was inserted through the pubic ramus and was driven deep into the substance of the ilium in the direction of the postero-inferior spine. The middle screw

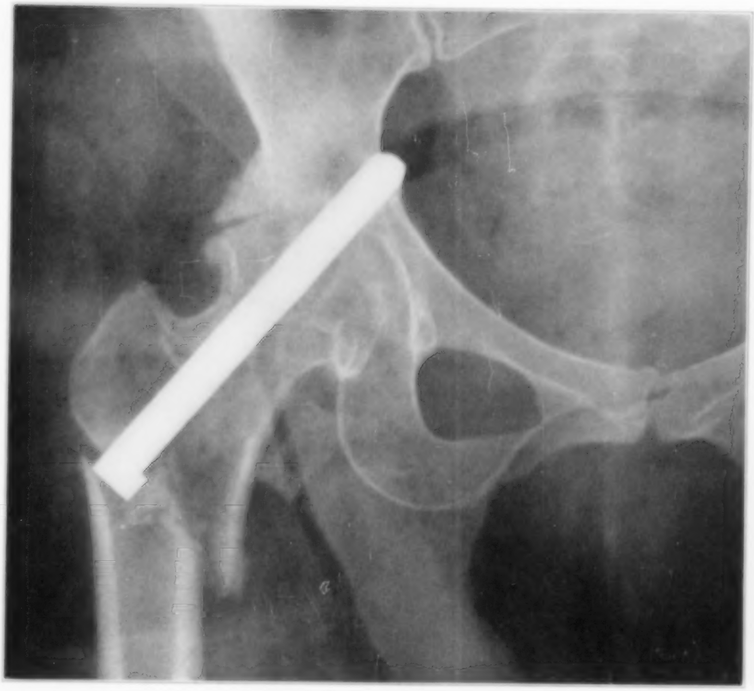


FIG. 7

The proximal head fragment was immobilized by straight nail fixation. The articular cartilage was not removed. In this case the osteotomy was performed at too oblique an angle, and the hip failed to fuse.

was passed through the femoral head into the posterior wall of the acetabulum, and the lower screw was placed in the femoral neck, in some instances being driven in as far as the posterior acetabular wall. In the later cases we have used four or even five screws, placing two screws into the pubic ramus, one into the femoral head, and two distally into the femoral neck. After the graft has been screwed into place, the soft tissues are retracted distally and the osteotomy is performed just above the level of the lesser trochanter. Holes are drilled across both cortices before the osteotomy is performed in order to avoid splintering of the shaft. In our cases the osteotomy did not displace the well anchored upper femoral fragment.

It appears that union is more likely to occur if the osteotomy is performed at the level of the lesser trochanter or slightly above this level. In the author's series some osteotomies were performed below the lesser trochanter, and in these cases the fragments took a longer period of time to heal. The osteotomy should be performed transversely, not obliquely, since slippage or displacement is thus less likely to occur (Fig. 7). It is believed that it is important not to displace the shaft inwardly, as is done with the usual McMurray osteotomy (Fig. 12). This displacement may result in delayed union or non-union at the osteotomy site.

There are occasions when a severe adduction-flexion contracture of the hip may be corrected by osteotomy without extensive intra-articular arthrodesis being performed (Fig. 8). This procedure decreases the magnitude of the surgery for some older people. In each instance the fragments at the osteotomy site are necessarily somewhat displaced, but they should always make good contact. In these patients, after excision of the capsule anteriorly and superiorly, the iliac graft is laid against the femoral head and neck and is

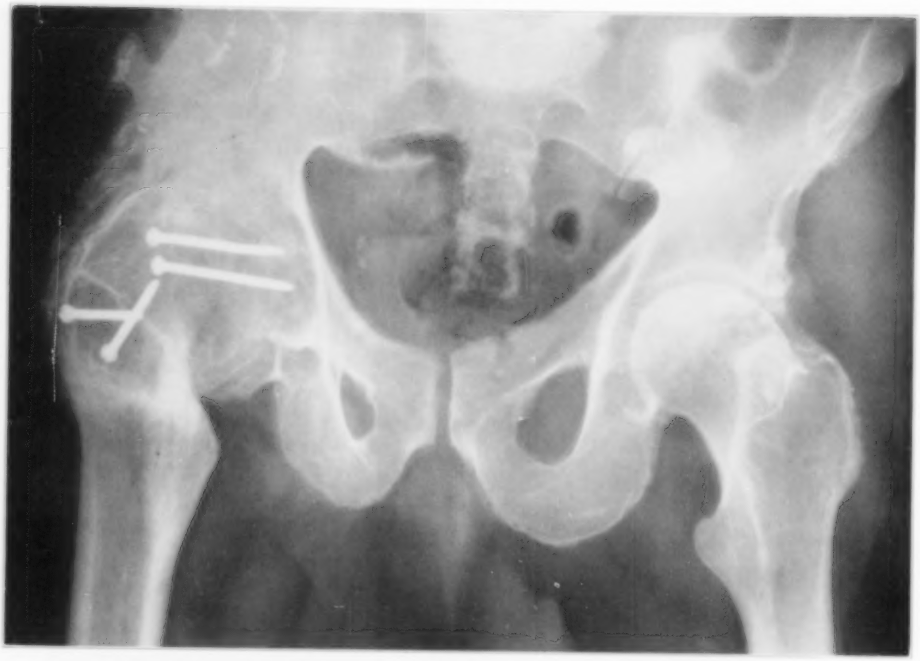


FIG. 8

Osteotomy was employed to correct a flexion-adduction deformity of the hip. The joint was not dislocated, and the articular cartilage was not removed.

screwed firmly into place; osteotomy is then performed to correct the deformity. Additional bone chips should always be placed superolaterally to aid in fusion and to provide the means by which adequate roentgenographic study of the progress of solidity may be made.

When the osteotomy is performed to correct an adduction-flexion contracture, the distal fragment of the femur must be left lying free in the corrected position; its proximal end must not be jammed against the head fragment, since this would negate the beneficial effects of the osteotomy in relieving the leverage stresses at the intended site of fusion.

### *Single Hip Spica*

A single hip spica is applied after the operation; the ankle is left free. If shortening of the leg does not have to be compensated for by fusion of the hip in a position of abduction, the best position for the hip is believed to be 5 degrees of adduction, neutral rotation, and 20 degrees of flexion. To obtain 20 degrees of flexion, the surgeon should hold the lower extremity parallel to the floor while the patient lies on the plaster-table and the spica is applied (Fig. 9). The limb should not be raised so that it forms an angle of 20 degrees with the floor, since this will ultimately result in 40 degrees of flexion, as tested by standard methods, and will cause an ungainly gait with lordosis and prominence of the buttock.

Ambulation may sometimes be begun within a week, but often a longer period of bed rest is required. A few patients, of course, need a prolonged period of bed rest, due to obesity or other factors. The spica is generally removed at the third month in order that adequate roentgenograms and a test of solidity may be made.

The problem of the stiff knee has not been overcome by the use of the single hip spica. In some of the first patients treated, the back of the leg and lower-thigh portion of the spica was cut out and knee motion was initiated with the patient lying prone in bed.

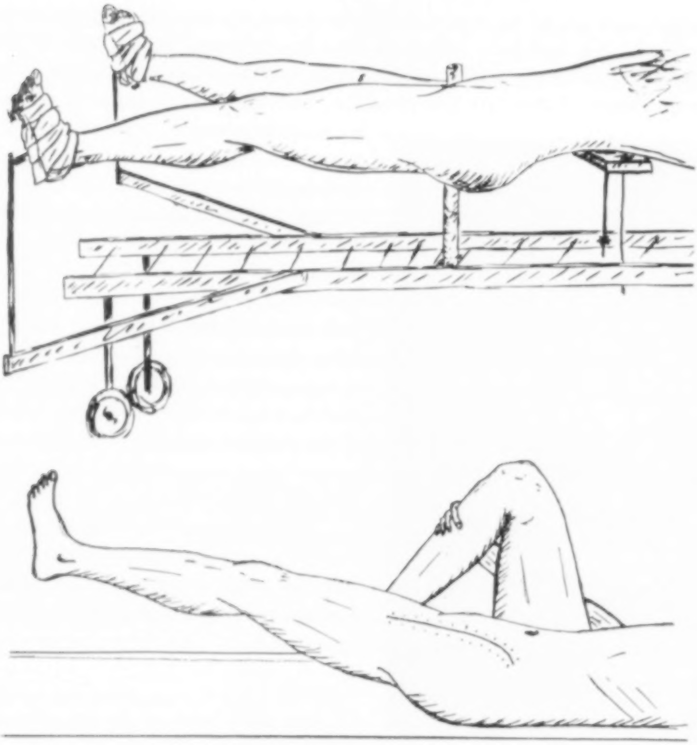


FIG. 9

If a single spica is applied with the lower extremity parallel to the floor, fusion occurs at 20 degrees of flexion, as can be seen when the lumbar spine is flattened.

In one case, vigorous stretching of the knee into flexion caused displacement of the fragments at the osteotomy site, and it took many months for solid union to occur. Furthermore, although knee motion in the patients treated in this manner was excellent during the first few weeks, it usually decreased steadily until a range of only ninety degrees was present. This range was only slightly greater than that obtained in the other patients without such treatment. This program is now rarely carried out; in most cases the danger is felt to be greater than the small advantage gained, and knee flexion is now obtained after the removal of the spica by the usual arduous active exercises and physiotherapy.

## POSTOPERATIVE COMPLICATIONS

Loss of position of the shaft fragments occurred in but one patient. In the other patients the fragments fused essentially in the positions in which they had been placed when the spica was applied.

Loss of the position of the head fragment resulted in coxa vara in one patient. This patient had been treated before the procedure of screwing the grafts to the ilium and femoral head was adopted.

One patient had a postoperative infection which ultimately healed. Solid fusion was obtained in this case.

There was one known instance of thrombophlebitis in the normal leg. This patient died suddenly at home two months following the operation.

One graft fell to the floor, was autoclaved, and was then placed in the slot cut in the femoral neck and ilium; solid fusion was obtained in this hip.

Subsequent fracture of some portion of the femur occurred in four patients in whom solid fusion of the hip had been attained. One fracture was at the base of the femoral neck, two were in the shaft, and one was in the supracondylar region (Fig. 10). There is a definite incidence of this late complication, and the possibility of its occurring must be considered when hip fusion is advised for a patient. In one of the patients with a mid-shaft fracture, plating and subsequent intramedullary nailing at another hospital had resulted in sepsis, which necessitated amputation of the leg. Two of the fractures were successfully treated by Jewett-nail fixation followed by application of a single hip spica. In patients with solid fusion of the hip, it takes a long time for a shaft fracture to heal because of the tremendous leverage effect of the distal fragment.

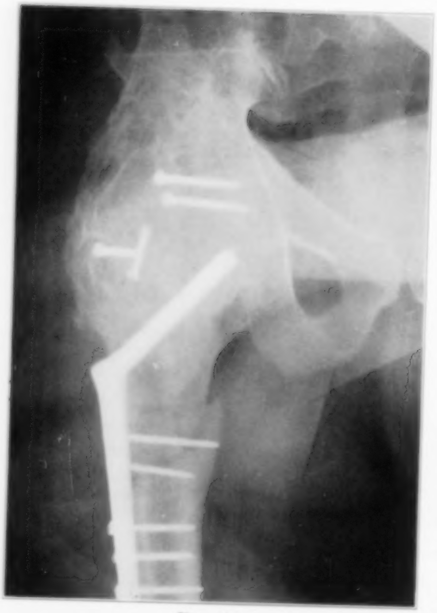


Fig. 10

Fig. 10: A late fracture of the femoral shaft occurred following solid fusion of the hip. This fracture was treated by the insertion of a Jewett nail and by the application of a single hip spica.

### *Age and Diagnosis*

Four patients were below the age of ten years; three were in their teens, three in their twenties, two in their thirties, seven in their forties, twelve in their fifties, and four in their sixties.

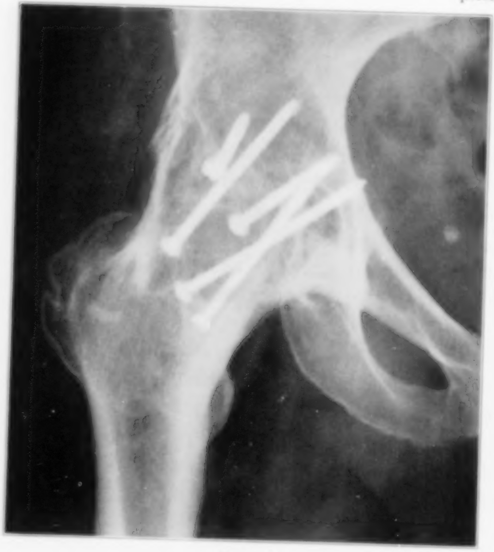


Fig. 11

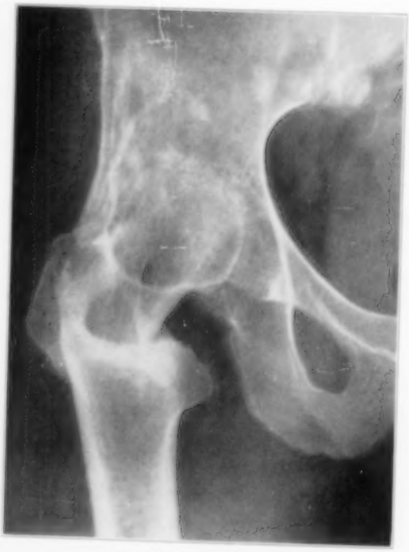


Fig. 12

Fig. 11: Five screws were used to fix the graft to the ilium and upper femur. Osteotomy was then performed. In the above roentgenogram the superior bone chips show well in silhouette. The fragments at the osteotomy site have united.

Fig. 12: Medial displacement of the shaft at the time of osteotomy may result in complications. In the patient shown in this roentgenogram, intra-articular fusion has been performed, a slot type of graft has been inserted, and bone chips have been placed superiorly.

In two of the children previous attempts to fuse the hips, which were tuberculous, had been made. In one of these children a pseudarthrosis was still present after five attempts at fusion; prompt solid arthrodesis occurred, however, when an osteotomy was performed during a sixth attempt.

In the other patients various degrees of osteo-arthritis occurred as the sequelae of residual suppurative arthritis, destructive arthritis, and aseptic necrosis of the head of the femur and also as the result of slipped epiphyses. The older patients could in general be placed in the category of malum coxae senilis.

## RESULTS

Of the thirty-five consecutive cases in which hip fusion was combined with osteotomy, thirty-four are available for study, one patient having died two months after the operation. In three of the thirty-four patients operated upon, primary solid fusion was not obtained at the site of arthrodesis; in one of these patients the fragments at the osteotomy site failed to heal, and a second operation was required to achieve union.

During the same nine-year period in which the above operations were performed, twenty hip fusions without osteotomy were also performed; early ambulation in a single spica was employed in these cases. The arthrodeses were of the intra-articular type, and screwed-on iliac grafts were not used. Pseudarthroses occurred in fourteen of the patients, an incidence of 70 per cent.

Prior to this period, twenty-three patients had been treated for osteo-arthritis by fusion without osteotomy and by the maintenance of a double hip spica for five months; the incidence of pseudarthrosis in these patients was 26 per cent.

## CONCLUSIONS

1. Subtrochanteric osteotomy performed at the time of primary hip arthrodesis has been helpful in lowering the rate of pseudarthrosis.
2. The use of a single hip spica in conjunction with osteotomy at the time of arthrodesis has not been harmful.
3. The single hip spica has allowed the earlier ambulation of the patient and in general has been successful in maintaining the desired position of the limb.
4. When possible, immobilization of the superior fragment by internal fixation and grafts is advised.

## REFERENCES

1. Farkas, Aladár: A New Operative Treatment of Tuberculous Coxitis in Children. J. Bone and Joint Surg., **21**: 323–333, Apr. 1939.
2. Ponseti, I.: Evolution and Treatment of Tuberculosis of Hip. Surg., Gynec., and Obstet., **87**: 257–276, 1948.
3. Stinchfield, F. E., and Cavallaro, W. U.: Arthrodesis of the Hip Joint. A Follow-Up Study. J. Bone and Joint Surg., **32-A**: 48–58, Jan. 1950.

## DISCUSSION

Dr. Alan DeForest Smith, New York, N. Y.: I am delighted to hear that Dr. Thompson still thinks that hip fusion is an excellent operation, for he is the designer of one of the best prostheses that there is. Because of recent enthusiasm for the hip prosthesis, it is sometimes forgotten that hip fusion is a good operation and that it is perhaps even the best procedure when the hip alone is involved. As has been mentioned, however, there are drawbacks to hip fusion, one being that failure of union is quite frequent in some series and another being that long immobilization is often required.

The advantages of combining osteotomy with hip fusion seem to me to be, first, that by this method one can obtain the optimum position of the head of the femur in relation to the ilium from the standpoint of obtaining fusion and yet not sacrifice functional position. I think that in the past we werely likely to compromise about this. If we tried to put the head in the best position with regard to the acetabulum, we found that the extremity was no longer in good functional position; and if we tried to put the head in the best functioning position possible and still get some apposition to the acetabulum, we usually did not quite succeed in doing either. Dr. Thompson's operation makes it possible to put the head in the best position for arthrodesis and then to correct the resulting deformity by doing an osteotomy. It seems to me that this is the chief advantage of his method.

The other advantage which is claimed for this method is that it eliminates the stress at the fusion site which is caused by small movements of the thigh. It probably does eliminate such stress for a time, but I wonder for how long; if union is going to take place, some solidity must occur fairly early. Dr. Thompson thinks consolidation occurs at seven weeks, and he may be correct; if so, then it is worth while performing an osteotomy to eliminate lever action. Dr. Thompson certainly has improved his results vastly by using this operation. Recently our results, obtained without osteotomy, have been somewhat better than they used to be. I believe that fusion now occurs in about 87.5 per cent of our cases.

The prevention of stiffness of the knee by cutting out the back of the cast I think is important, and I am not sure that everyone uses this technique. By that means we have been able to prevent stiffness of the knee, or at least to maintain motion up to 90 degrees, which I think is important. Of course, the ideal procedure would be to obtain such firm internal fixation that a cast would not be necessary at all. I used screws successfully in one patient, but have not been able to do so again. In a few other patients we have obtained firm internal fixation with a long Smith-Petersen nail. I still believe that the head should be dislocated and that all vestiges of cartilage should be removed from the head and acetabulum and also that it is an advantage to make multiple drill holes through the head and acetabulum in order to promote circulation at the fusion site. I do not believe that the Smith-Petersen nail alone can be counted upon to accomplish arthrodesis. However, in a patient who cannot stand a major procedure but who is having a great deal of pain, insertion of the nail alone in a comparatively minor operation can bring relief for at least a year. Of course, when the nail loosens and comes out, fixation is lost; I have not seen any case where fusion has been obtained by the use of the nail alone.

H. W. Smith used osteotomy in his hip fusions for tuberculosis some time ago; he knew nothing about Dr. Thompson's series, however, and I know that Dr. Thompson did not know anything about his. As far as I know, Dr. Smith reserved this method for the treatment of tuberculosis, but I think it applies equally well and perhaps even better to the treatment of osteo-arthritis.

Dr. Thompson (closing): I am sure that surgeons have been combining osteotomies with hip fusions for many years. Probably Sir Robert Jones performed this operation, and apparently Dr. Smith performed it before I was even in training. Osteotomy is an excellent addition to the standard procedure and seems to be effective in hastening fusion as well as in assuring a high percentage of fusion.

The type of postoperative fixation that we have been using is the single hip spica, which is continued for three months. With the single hip spica, the hips in our series fused solidly by the time the fragments at the osteotomy site had united. Dr. L. Wagner tells me that he removes the spica after eight weeks; I have been afraid to remove it so early, but he feels that fusion is solid by that time. I do not know exactly how long it takes for the fragments at the osteotomy site to heal. I know they are not united in one week, and I think it is about seven weeks before the leverage effect begins to operate again.

# INTERNAL FIXATION IN DISPLACED INTRACAPSULAR FRACTURES OF THE FEMORAL NECK *

BY GEORGE O. EATON, M.D., BALTIMORE, MARYLAND

The purpose of this paper is to advocate shaft fixation in the nailing of displaced acute fractures of the femoral neck. Much has been written on the subject of the so-called "unsolved fracture". In 1953, the Chairman's Address to the Section on Orthopaedic Surgery of the American Medical Association [9] was on this subject, and the Presidential Address to The American Orthopaedic Association [4], in the same year, was a memorable discussion of this same problem. At last year's meeting of the Academy, Cleveland and Fielding reported the experiences of the St. Luke's Hospital Staff. Of sixty-three cases of displaced femoral-neck fractures which required manipulative reduction, they reported union in 77.7 per cent. Boyd and George in a study of 300 acute displaced femoral-neck fractures reported bony union in 86.5 per cent.

Many explanations have been offered for the high percentage of non-union following treatment of this fracture. Chief among these have been a meager blood supply, the failure to secure anatomical reduction, the usually advanced age of the patient, and the risks of prolonged immobilization. Comparatively little emphasis has been placed on the importance of efficient immobilization in determining the outcome of treatment.

In impacted fractures of the femoral neck bony union occurs unless there is disimpaction. Disimpaction may occur if impaction is in varus position or in marked retroversion. If impaction is in valgus position, very little strain is put on the fixation of the fragments and the results are excellent with respect to bony union. Anatomical reduction is seldom present, age is advanced, blood supply is meager and at least partially interrupted,

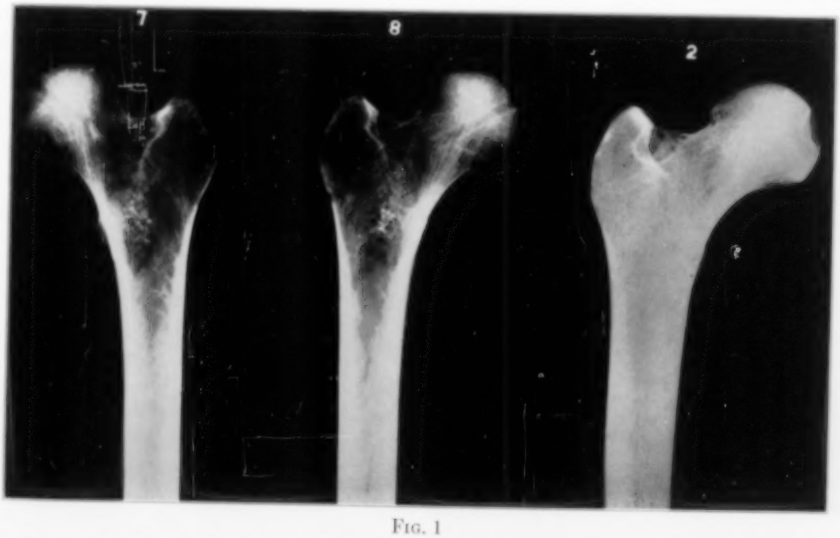


FIG. 1

Roentgenograms of three femora, selected at random from anatomy-laboratory specimens, reveal the marked variation in density of cancellous tissue even though there was marked similarity in the external appearance of the three specimens.

---

* Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Los Angeles, California, February 2, 1955.

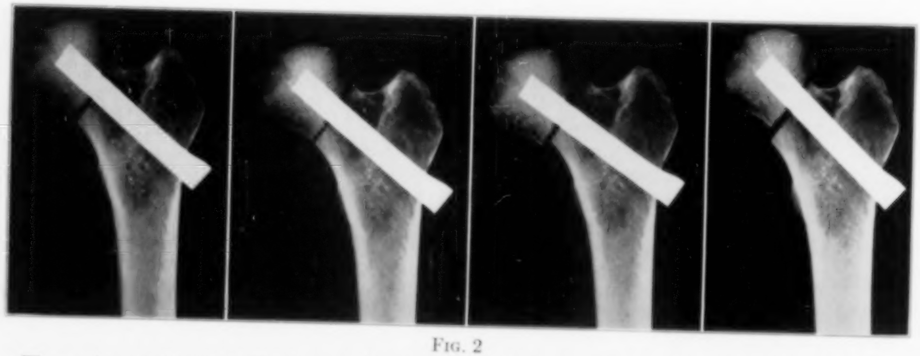


FIG. 2

The specimen on the left in Fig. 1 was nailed with a straight nail. After cutting the femoral neck to simulate a fracture, gentle manipulation produced marked instability of the fixation in all directions. Compare with drawings *a*, *b*, and *c* in Fig. 6.

but bony union takes place. In Cleveland's series, bony union occurred in all impacted fractures.

In choosing the type of internal fixation to be used in fresh displaced fractures of the femoral neck, more emphasis should be placed on the degree of immobilization to be expected. The osseous texture of the femoral head is such that a good grip is usually obtained by a straight flanged nail, or screw, or a series of pins or wires. The trabecular pattern so closely woven in the head becomes more and more loosely arranged and the density of the cancellous structure diminishes as the lesser trochanter is approached (Fig. 1). There is a triangular area, Ward's triangle, in the neck of the femur which may be almost devoid of trabeculae. The osteoporosis increases with age and lack of activity. Hence, the only grip we have on the distal fragment is at the cortex of the trochanter which in the aged may be so rarefied that it resembles an eggshell in fragility. Thus, in a so-called "bull's eye" nailing, up the center of the neck, the trochanteric cortex serves as a fulcrum and allows motion at the fracture site no matter whether a straight nail or wires or screws are used. Motion is possible in a vertical plane in two directions (Fig. 2) and, in addition, there is no protection against alternating compression and distraction at the fracture line. A steep placement of the nail should prevent downward motion of the head in the vertical plane but does not protect against upward motion or compression and distraction of the fracture line.

To what degree is non-union and excessive absorption of the femoral neck due to excessive motion at the fracture site in bone which admittedly is poor in blood supply? We can remember when non-union of the carpal navicular was the rule until improved immobilization was utilized and non-union became the exception. Marked absorption at the fracture line and consequent shortening and deformity are common in Colles's fractures which are usually not immobilized above the elbow with a consequent comparative loss of immobilization of the radial fragments. Is non-union in tarsal bones much less common than in carpal bones because our relative immobilization of a foot is much more efficient? Bennett has shown that non-union of a humeral shaft fracture can be successfully treated by conversion to an oblique fracture and internal fixation with screws. Control of motion of the fragments is most important for the protection of minute blood channels which are the most important requisite to the production of callus. Some bones such as ribs and pelvic bones produce abundant callus and will generally heal in spite of motion, thanks to their abundant blood supply. Other bones, of which the neck of the femur is the leading example, demand efficient and complete immobilization because of comparatively precarious circulation.

A few Dickson geometric osteotomies (Figs. 3-A through 5-B) were done for non-union of femoral-neck fractures. Each series of roentgenograms shows the preoperative condition and the postoperative result, with bony union of the neck of the femur. All that was done in order to convert non-union into bony union was to rotate the fracture line so that an impacting factor was added, and by nail-plate fixation the fracture site was efficiently immobilized. No bone-grafting was used in any of these patients.

At the 1948 meeting of The American Academy of Orthopaedic Surgeons, Dr.

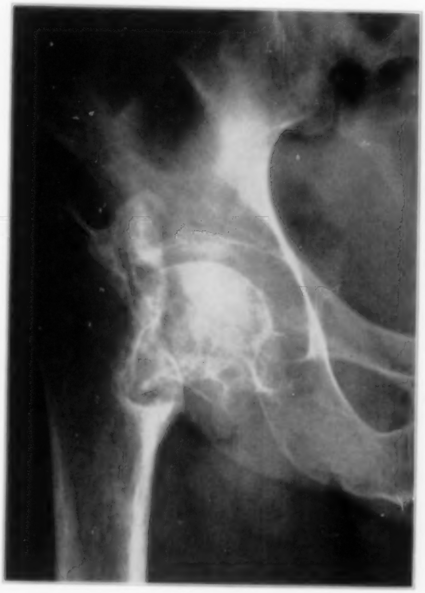


Fig. 3-A

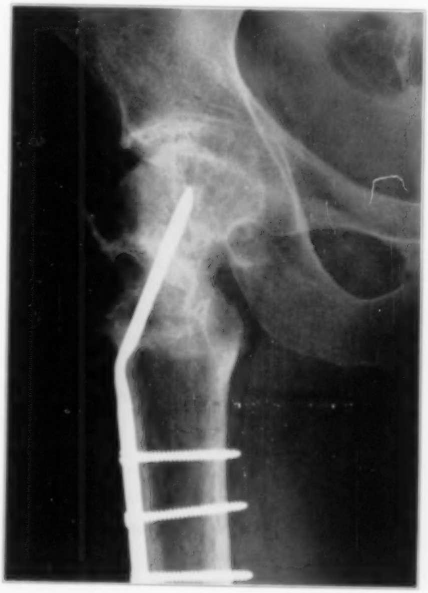


Fig. 3-B

Figs. 3-A to 5-B: Dickson geometric osteotomies done for non-union of femoral-neck fractures. Each series shows first the preoperative condition and then the postoperative result.

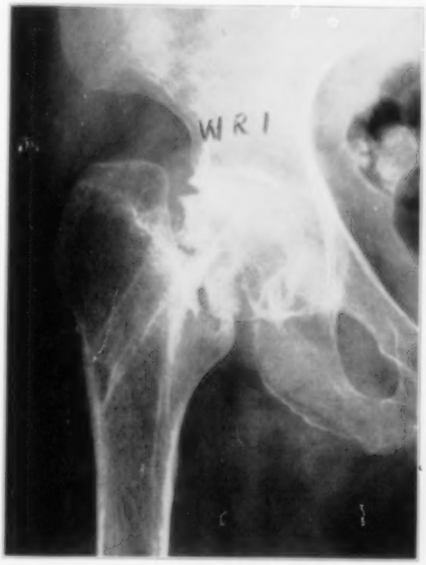


Fig. 4-A

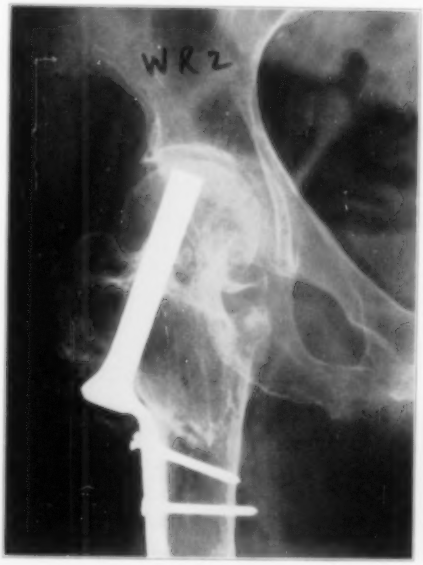


Fig. 4-B

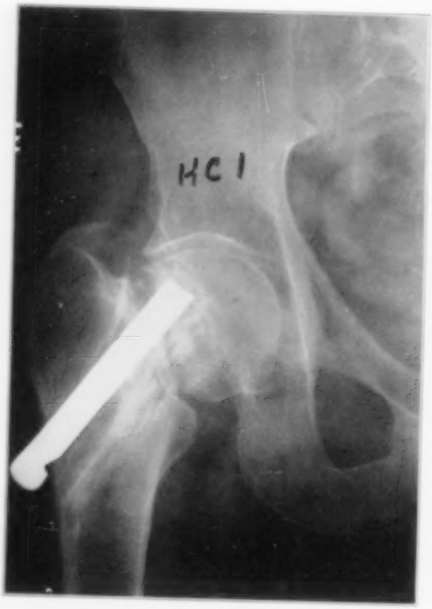


FIG. 5-A

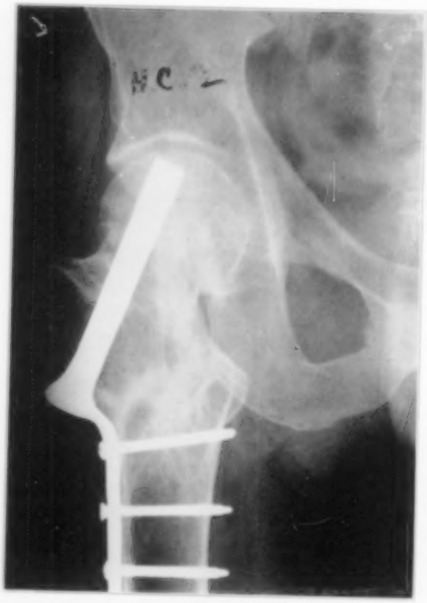


FIG. 5-B

Edward J. Haboush presented an exhibit on photoelastic stress and strain analysis in cervical fractures of the femur. He demonstrated that a nail-plate is the ideal appliance and should be inserted in the low position so that it rests on the calcar femorale distal to the point of fracture (Fig. 6).

In an effort to lower the percentage of poor results following the insertion of a Smith-

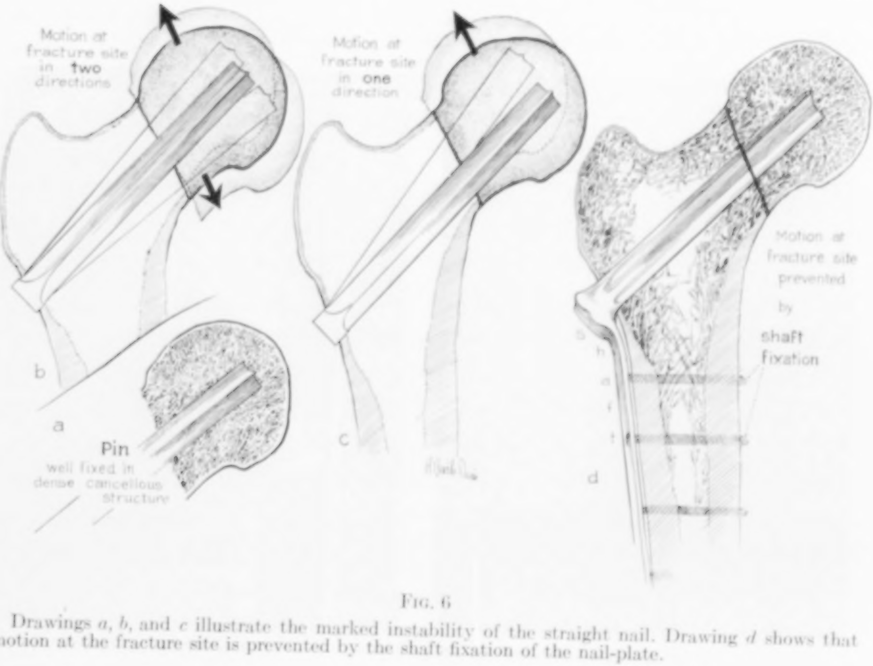

Motion at fracture site in two directions
Motion at fracture site in one direction
Motion at fracture site prevented by shaft fixation
b
a
Pin well fixed in dense cancellous structure
c
d
s
h
a
f
t

FIG. 6

Drawings *a*, *b*, and *c* illustrate the marked instability of the straight nail. Drawing *d* shows that motion at the fracture site is prevented by the shaft fixation of the nail-plate.

Petersen nail, the author began, in 1951, to use a nail-plate for all displaced femoral head and neck fractures. The author is aware that in several communities and clinics the straight nail has been discarded in favor of the nail-plate. In 1952, Jewett reported to the Southern Medical Association the experience of his group in the use of nail-plate fixation in fractures in the subcapital and intracapsular area of the femoral neck.

The author's series is small—the total number is thirty-six; twenty-six were done more than one year ago. Of these twenty-six patients, eight were lost to follow-up: five having died from other causes within twelve months and another being out of reach in South America. In two patients, the nail-plates were removed because of septicaemia three weeks after operation and because the nail-plate extruded from the femoral head three weeks after operation. In the remaining eighteen patients clinical union has occurred.

## CASE REPORTS

CASE 1. Mrs. M. W. B., aged fifty-four, sustained an intracapsular fracture of the neck of the right femur with displacement of fragments on March 17, 1951. Blind nailing was performed on the date of injury. There were no complications. A roentgenogram made twelve months after operation revealed bony union and excellent alignment. The nail was removed because of lateral thigh pain on November 18, 1952. She was discharged from active treatment on December 10, 1952.

CASE 2. Miss E. G., aged eighty-two, sustained an intracapsular fracture of the left femur with displacement of fragments on June 14, 1951. Blind nailing was performed on the date of injury. Convalescence was uneventful. The final roentgenogram made on June 9, 1952, revealed sound healing with the nail slightly perforating the femoral head. The patient was walking with very little discomfort. The nail will be removed if discomfort increases. She was discharged from active treatment.

CASE 3. Mrs. J. N., aged seventy-five, sustained an intracapsular fracture of the left femur with displacement of fragments on June 1, 1951. Smith-Petersen blind nailing was done on the date of injury, with low implantation. A check roentgenogram made ten days later revealed a fracture of the trochanteric cortex, with partial extrusion of the nail, and coxa vara. On June 15, 1951, renailing was done with a Jewett-type nail. Convalescence was uneventful. On June 5, 1952, the nail and screws were removed from the hip because of protrusion of the nail through the femoral head; good bony union was apparent. She was last seen in May 1955. The femoral-neck fracture was soundly healed. Definite arthritic and aseptic necrotic changes were present about the femoral head.

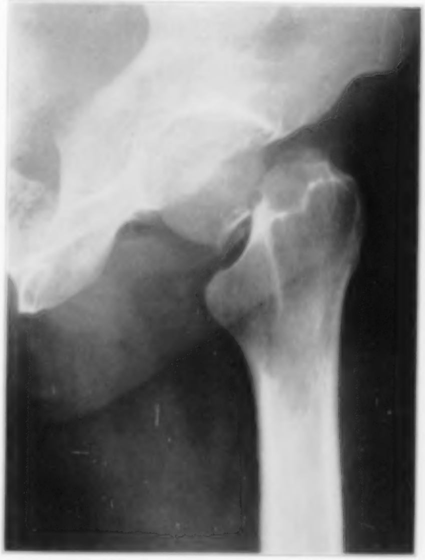


FIG. 7-A

Case 5. J. L. W. February 1, 1952.

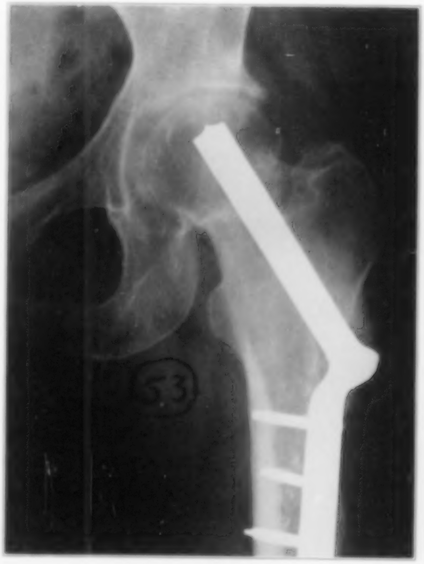


FIG. 7-B

Result eight months postoperative.

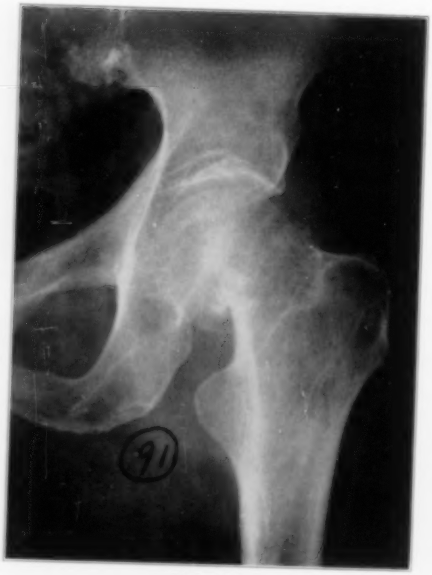


Fig. 8-A
Case 11. M. B. R. May 23, 1952.

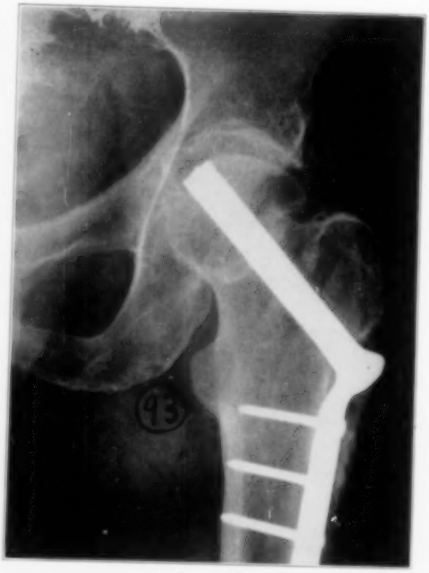


Fig. 8-B
Final roentgenogram, December 17, 1953.

Case 4. Miss E. S., aged seventy-two, sustained an intracapsular fracture of the left femur, with displacement of fragments on January 22, 1952. Blind nailing (Jewett) was performed on the date of injury. There were no complications. The patient began weight-bearing against advice before the check roentgenogram was made twelve weeks after operation. A follow-up roentgenogram made one year after operation revealed bony union of the fracture of the neck of the femur and excellent alignment.

Case 5 (Figs. 7-A and 7-B). Mrs. J. L. W., aged fifty-five, sustained an intracapsular fracture of the left femur with displacement of fragments on February 1, 1952. A blind nailing (Jewett) was performed on February 2, 1952. The patient had an unexplained low-grade temperature elevation following operation. Repeated roentgenograms of the hip were negative, but pain persisted; because of continued pain, the nail was removed on November 17, 1952. Union was apparently sound. Subsequent follow-up roentgenograms showed a moderately severe arthritic reaction in the hip with aseptic necrosis of the femoral head. The patient is still under observation. No further surgical measures have been planned. She walks with a cane.

Case 6. Mrs. H. M. B., aged eighty-five, sustained an intracapsular fracture of the right femur with displacement of fragments on February 15, 1952. Blind nailing (Jewett) was performed on February 18, 1952. The check roentgenogram made twelve weeks after operation showed good alignment with essentially no absorption. She was allowed to begin partial weight-bearing. The final roentgenogram, made on December 7, 1953, showed a very satisfactory position of the femoral head, with bony union and very little absorption of the neck. The patient walks with the aid of a companion because of loss of a sense of balance.

Case 7. Miss M. H., aged sixty-eight, fell downstairs, sustaining an intracapsular fracture of the right femoral neck plus dislocation of the right shoulder on March 3, 1952. Blind nailing (Jewett) of the hip was done on March 4, 1952. Recovery, as regards the hip, was uneventful. The final roentgenogram made on April 13, 1952, showed apparent bony union and a very satisfactory alignment. The patient was discharged from active treatment.

Case 8. Miss L. P. G., aged sixty-two, sustained a subcapital fracture of the neck of the left femur on March 24, 1952. Blind nailing (Jewett) was performed on March 25, 1952. A three-week postoperative roentgenogram revealed extrusion of the nail from the femoral head. It was noted at operation that the bone texture seemed to be soft; the patient was very heavy. The hip was renailed with a Jewett nail followed by immobilization in a single spica cast for six weeks. Following the second operation, the patient had an uneventful convalescence. A check roentgenogram made fourteen months after the second operation revealed apparent bony union and good alignment with some absorption of the femoral neck. A roentgenogram made one year later revealed definite mild-to-moderate aseptic necrosis of the femoral head. There were insufficient symptoms to justify removal of the Jewett nail. The patient, still under observation, is walking with the aid of a cane.

CASE 9. Mrs. B. S., aged eighty-eight, sustained an intracapsular fracture of the neck of the femur, with displacement of fragments on May 21, 1952. Nailing was performed on the date of injury. The convalescence was uneventful. A roentgenogram made on April 29, 1953, revealed excellent alignment and apparent bony union, with a slight degree of aseptic necrosis of the femoral head.

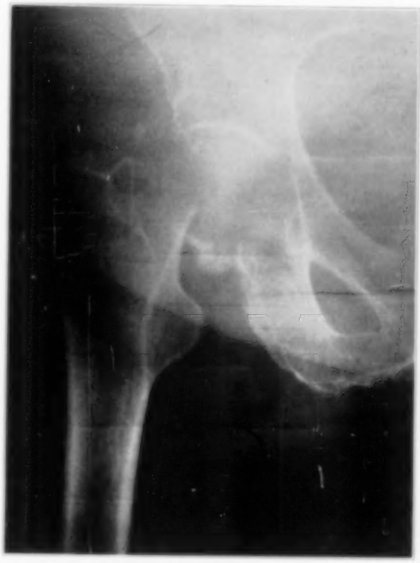


FIG. 9-A
Case 15. R. C. April 2, 1953.

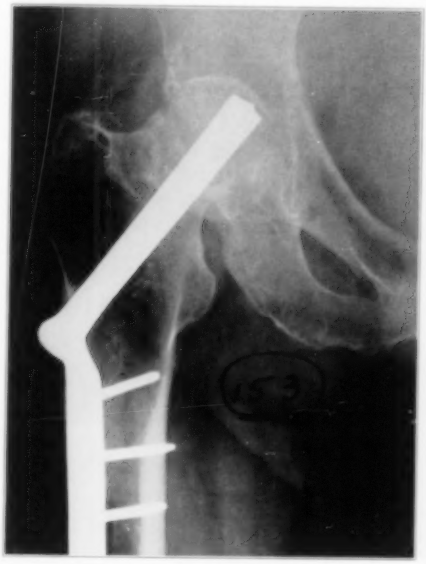


FIG. 9-B
Result twelve months postoperative.

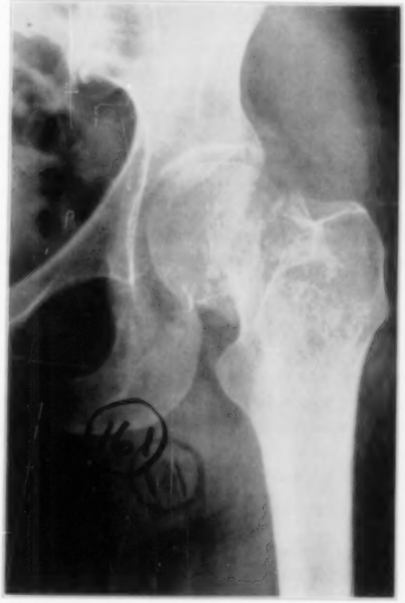


FIG. 10-A
Case 16. O. W. B. April 27, 1953.

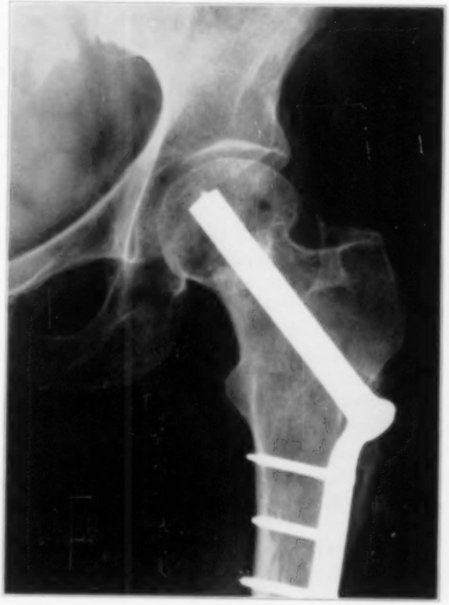


FIG. 10-B
Result twelve months postoperative.

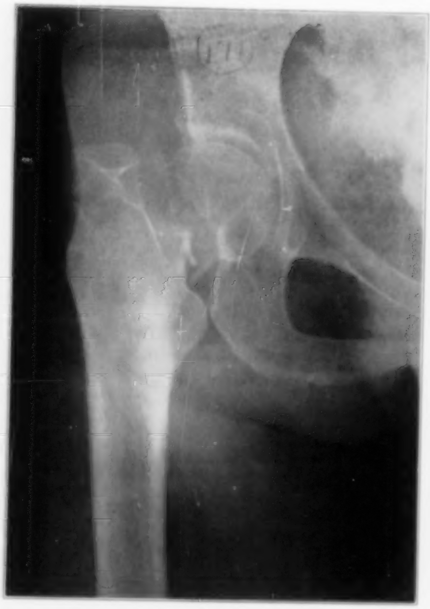


Fig. 11-A

Case 17. A. T. L. September 23, 1953.

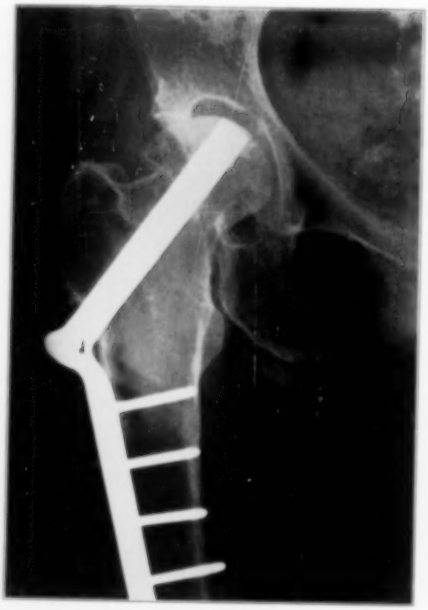


Fig. 11-B

Result twelve months postoperative.

Case 10 (Figs. 8-A and 8-B). Miss M. B. R., aged seventy-nine, sustained an intracapsular fracture of the neck of the left femur, with displacement of fragments on May 12, 1952. Blind nailing (Jewett) was performed on May 23, 1952. The patient had an uneventful convalescence. She was allowed to begin weight-bearing in approximately four months. The final roentgenogram on December 17, 1953, revealed apparent bony union in mild valgus. The nail protruded slightly beyond the femoral head and removal was recommended but was declined by the patient. She was discharged from active treatment. She walks with mild discomfort.

Case 11. Mrs. McC., aged sixty-five, sustained an intracapsular fracture of the neck of the right femur, with displacement of fragments on May 19, 1952. Blind nailing (Jewett) was performed on May 21, 1952. The patient also had a fracture of the right wrist. The convalescence was uneventful. Roentgenograms made on January 26, 1955, showed apparent bony union. There was no pain or limp. The patient was discharged from further treatment.

Case 12. Mr. M. H., aged forty-five, in a farm accident on October 23, 1952, sustained a fracture of the femoral neck, with displacement of fragments. Blind nailing (Jewett) was done on October 24, 1952. The convalescence was uneventful. A roentgenogram made twelve months later showed apparent bony union with mild coxa valga. The nail and screws were removed on February 5, 1954, because the patient was comparatively young and there was no further need for the appliance. No protrusion of the nail through the femoral head had occurred.

Case 13. Mr. J. B., aged sixty-eight, sustained a subcapital fracture of the right femoral neck, with displacement of fragments on January 12, 1953. Blind nailing (Jewett) was performed on January 12, 1953. The patient also had a fracture of the distal portion of the right radius. The convalescence was uneventful. Roentgenograms made on February 2, 1954, showed good alignment and apparent bony union. The patient was discharged from further treatment.

Case 14. Mrs. M. A. R., aged seventy-four, sustained an intracapsular fracture of the left femur with displacement of fragments on November 15, 1952. Blind nailing (Jewett) was performed on November 19, 1952. Pyelocystitis was a complication. Roentgenograms made about one year after injury showed apparent bony union. The patient uses a cane during part of the time. She was discharged from treatment in November 1954.

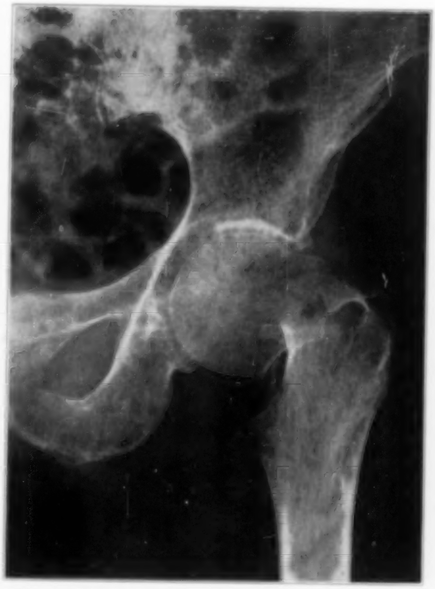


FIG. 12-A

Case 18. W. F. B. October 10, 1953.

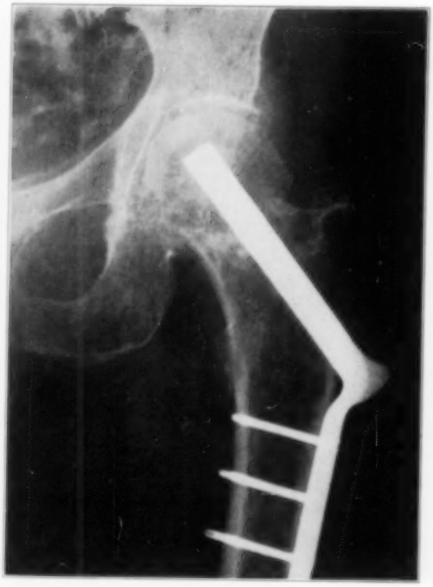


FIG. 12-B

Result eleven months postoperative.

CASE 15 (Figs. 9-A and 9-B). Mrs. R. C., aged eighty-nine, sustained a subcapital fracture of the neck of the right femur on March 27, 1953. Blind nailing (Jewett) was performed on April 2, 1953. The convalescence was uneventful. A final roentgenogram showed apparent bony union with slight absorption and slight protrusion of the nail. The patient was sufficiently comfortable, however, and removal of the nail was not considered to be justified in view of the minimal degree of discomfort.

CASE 16 (Figs. 10-A and 10-B). Mrs. O. W. B., aged fifty-two, sustained an intracapsular fracture of the left femoral neck on April 22, 1953. Blind nailing (Jewett) was performed on April 27, 1953. The convalescence was uneventful. Partial weight-bearing on crutches was allowed five months after the injury. Final roentgenograms revealed apparent bony union and excellent alignment. The patient was discharged on March 5, 1954.

CASE 17 (Figs. 11-A and 11-B). Miss A. T. L., aged seventy-three, sustained an intracapsular fracture of the neck of the right femur on September 23, 1953. Blind nailing (Jewett) was performed on the date of injury. The convalescence was uneventful. A roentgenogram made one year later revealed apparent bony union with very good alignment. Unlimited weight-bearing was allowed. On January 3, 1955, the nail and screws were removed because of protrusion through the femoral head. No further treatment was indicated.

CASE 18 (Figs. 12-A and 12-B). Mrs. W. F. B., aged sixty-five, sustained an intracapsular fracture of the neck of the left femur on October 10, 1953. Blind nailing (Jewett) was carried out on the date of injury. The patient had been under treatment for several years because of multiple myeloma. Convalescence was uneventful. A roentgenogram made one year later revealed apparent bony union with very good alignment. Sixteen months after operation the patient died of complications due to multiple myeloma.

## DISCUSSION

Standard methods of manipulative reduction were used, always with an attempt to get slight overreduction so as to obtain a valgus position of the head, if possible. The nailing was done under x-ray control—the so-called blind nailing; open reduction was avoided. Frequently, operating-room roentgenograms were of poor quality. In two patients, the nail became disengaged from the head and re-nailing had to be done weeks later; the patients were put in plaster spica casts for six weeks. The spica would seem to be indicated for additional support in patients in whom the limb is heavy or the bone texture seems to be soft. Except for these two patients, no additional immobilization was employed. Motion, but no weight-bearing, was allowed. Weight-bearing was usually permitted after a twelve-week check roentgenogram had been made.

Two main objections are made to the use of the nail-plate. The first is the prolongation of the time of operation. This does not in itself constitute a valid objection. The additional exposure necessary to introduce a nail with a shaft plate can be accomplished while waiting for the roentgenograms of the guide-pin placement to be developed. Second, there is the danger of protrusion of the nail through the head and into the acetabulum in the post-operative healing period. In this series of thirty-six cases this has not occurred to an objectionable degree. Three nails have been removed because of protrusion after firm bony union appeared to be established. In one patient, removal of the nail was advised but was declined by the patient. In one patient the nail was removed because of discomfort from apparent foreign-body reaction. The added immobilization has quite possibly been responsible for a decrease in the degree of absorption of the neck during the healing period of the fracture.

The factor of bone density plays a part in determining the efficiency of fixation by any type of appliance; this may be directly related to variations in tolerance of bone to metallic insertions. Protrusion of the nail through the femoral head, which occurred in about 35 per cent of these reported cases, may also be related to the same factors. When it does occur, it is a small price to pay for the increased chance of clinical union which nail-plate fixation appears to offer.

Anatomical reduction is not absolutely essential to union. Slight overreduction in valgus, in our opinion, is to be preferred, although it is not always obtainable. Bony union, judged by clinical standards, has occurred in eighteen consecutive patients in whom the nail was kept *in situ* for one year.

This report concerns itself only with the question of bony union of displaced intracapsular fractures of the femur. The series is much too small for valid conclusions to be drawn as regards the incidence of aseptic necrosis as a complication of high femoral-neck fractures treated by nail-plate fixation.

In conclusion, the use of a combination flanged nail and plate in displaced femoral-neck fractures is recommended as a safe procedure and, because of more efficient immobilization, one which is more apt to result in bony union.

## REFERENCES

1. Boyd, H. B., and George, I. L.: Complications of Fractures of the Neck of the Femur. J. Bone and Joint Surg., **29:** 13–18, Jan. 1947.
2. Bennett, G. E.: Fractures of the Humerus with Particular Reference to Non-Union and Its Treatment. Ann. Surg., **103:** 994–1006, 1936.
3. Cleveland, Mather, and Fielding, J. W.: A Continuing Study of Intracapsular Fracture of the Femur. J. Bone and Joint Surg., **36-A:** 1020–1030, Oct. 1954.
4. Dickson, J. A.: The Unsolved Fracture. A Protest Against Defeatism. J. Bone and Joint Surg., **35-A:** 805–822, Oct. 1953.
5. Dickson, J. A.: Personal communication.
6. Haboush, Edward J.: Photoelastic Stress and Strain Analysis in Cervical Fractures of the Femur. Bull. Hosp. Joint Dis., **13:** 252–258, 1952.
7. Jewett, E. L.: Personal communication.
8. Jewett, E. L.; Albee, Fred H., Jr.; and Stanford, F. DeW.: Treatment of All Fractures of the Upper End of the Femur With the Original One-Piece Flange Nail. Southern Med. J., **46:** 920–924, 1953.
9. McCarroll, H. R.: Has a Solution for the "Unsolved Fracture" Been Found? Problems and Complications of Fractures of the Femoral Neck. J. Am. Med. Assn., **153:** 536–540, 1953.

# OSTEOTOMY AND OSTEOTOMY COMBINED WITH BONE-GRAFTING FOR NON-UNION FOLLOWING FRACTURE OF THE FEMORAL NECK *

BY MARCUS J. STEWART, M.D., AND R. E. WELLS, M.D., MEMPHIS, TENNESSEE

*From the Campbell Clinic and the Department of Orthopaedic Surgery,*
*the University of Tennessee, Memphis*

Non-union and late degenerative changes following fractures of the neck of the femur continue to present one of the major orthopaedic problems of our day. The present accepted methods of treatment for ununited fractures of the femoral neck include bone-grafting, osteotomy, arthrodesis, reconstruction, and insertion of the recently popularized femoral-head prosthesis.

Barton first performed the high-femoral osteotomy in 1826. Kirmission, von Baeyer, Lorenz, and Schanz made noteworthy contributions about the turn of the century, and important innovations were made by Haas, McMurray, Milch, and Batchelor. Many other contemporary workers have added materially to our knowledge of osteotomy. Pauwels and Linton contributed important information with respect to the shearing force at the fracture site and described accurate methods of measuring the angle of the fracture. In 1944, Linton recommended that a primary wedge osteotomy be performed at the time of nailing in a patient with a "steep" femoral-neck fracture. This osteotomy converts the shearing force at the fracture site into a compression force.

Reich, McMurray [16], Schumm, and Cleveland, Bosworth, and Della Pietra, among others, have reported series of patients upon whom modifications of the osteotomy were performed.

In our experience the low-angulation osteotomy with internal fixation, as described by Blount [4,5], has proved the most satisfactory method. Angulation at the site of osteotomy provides good weight-bearing alignment. Internal fixation by means of a blade-plate, as recommended by Blount [4], with the addition of two Knowles pins, as suggested by Moe, is adequate to maintain good alignment after correction of coxa vara, anteversion, rotation, or any other angulation. Healing of the fragments at the osteotomy site occurs promptly, and no cast or external fixation is necessary.

In 1947, Dickson [14,15], criticized the "either-or" approach — either osteotomy or bone-grafting. It was at this time that he introduced his geometric osteotomy combined with bone-grafting. This operation was an innovation in that a 60-degree angle of valgus was accurately produced and controlled. Iliac cancellous bone was inserted as a graft through a window in the femoral neck. He has recently stated that an angle of correction of slightly less than 60 degrees, that is, an angle approaching 45 degrees, is desirable. He pointed out that this type of osteotomy may increase the length of the limb as much as one and one-half inches.

Cleveland, Bosworth, and Della Pietra developed the spline type of blade-plate. They recommended more than 60 degrees of abduction at the site of the osteotomy for the best results, and they advised against the use of a bone-graft supplement.

Dickson has demonstrated that a so-called "dead head" can be revascularized by osteotomy and bone-grafting and may be made normal in both appearance (as shown by roentgenograms) and function. He has further emphasized that, following internal fixation of a fracture of the femoral neck, the first sign of change of position at the fracture site or of vascular changes in the head is an indication for osteotomy and bone-grafting.

---

* Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 24, 1954. Revision received for publication, January 29, 1955.

## RECONSTRUCTIVE PROCEDURES

In an attempt to solve the problem of non-union, arthritis, and avascular sclerosis following fracture of the femoral neck, many acceptable operations have been devised. Some of the more popular of these procedures are the Whitman, the Albee, the Brackett, and the Magnuson modification of the Brackett, the Luck, the Wilson, and the Colonna.

Magnuson, in 1932, described his modification of the Brackett operation and reported seventeen cases in which the results were satisfactory. He recommended postoperative immobilization in plaster-of-Paris for eight weeks. Magnuson's statement, made twenty-three years ago, that "probably no other common fracture has been so completely and consistently disabling as fracture of the neck of the femur" is still true.

## CIRCULATION AND AVASCULAR SCLEROSIS

Boyd and George, reporting on a large group of fractures of the femoral neck, observed that avascular sclerosis developed in 59 per cent of the patients in whom the fractures failed to unite, while similar avascularity developed in 32 per cent of the patients in whom the fractures did unite. Of their entire group of patients followed for two years or longer, 33 per cent had severe degenerative arthritic changes.

Phemister showed that gradual substitution of an avascular necrotic femoral head can take place, although the replacement is usually slow, spotty, and irregular. He believed that in his cases drilling of the head removed much of the sclerotic bone and that the insertion of two cortical-bone grafts aided immobilization, prevented pathological fracture and collapse of the head, and hastened revascularization. Phemister recommended that drilling and bone-grafting be carried out as soon as the presence of avascular necrosis of the head is established and said that this process could restore the integrity of the head.

Since the slowness of the revascularization of the superior lateral portion of the head may be responsible for the fragmentation and collapse of the head, Phemister held that no weight-bearing should be allowed for approximately two years. It was his opinion that in his cases drilling and bone-grafting accelerated the revascularization and thus shortened the period of non-weight-bearing.

Santos, in 1930, and Wolcott, in 1933, demonstrated that the ligamentum teres makes an important contribution to the vascularity of the head regardless of the age of the patient. Santos states that if a fractured neck unites to a necrotic head, creeping substitution may revascularize the head.

Trueta and Harrison have recently reported an extensive study of the circulation in the proximal portion of the femur. They state that in the femoral head there is no decrease in the patency of the vessels with advance in years. Normally, the lateral epiphyseal artery, derived from the medial femoral circumflex artery, supplies three-fourths of the blood of the epiphyseal portion of the head; and the inferior metaphyseal artery, derived from the same source, supplies two-thirds of the blood of the metaphyseal portion.

These authors believe that when the head is in abduction, the most important portion of the vascular tree is relaxed. They feel that an adduction fracture, with the neck in the varus position, tends to tear the tissues at the point of entrance of the lateral epiphyseal artery and thus to disrupt the nutrition of the superior lateral weight-bearing portion of the head.

Thus, there is considerable evidence to substantiate the view that a fracture of the femoral neck severs the major portion of the vascular tree supplying the capital part of the bone. Although a number of fresh fractures may fail to unite, the restoration of circulation to the femoral head remains the problem of paramount importance.

## OSTEOTOMY

The normal femoral head is far superior to any artificial appliance, and if union cannot be established within a reasonable time and if the patient is not senile, measures to restore

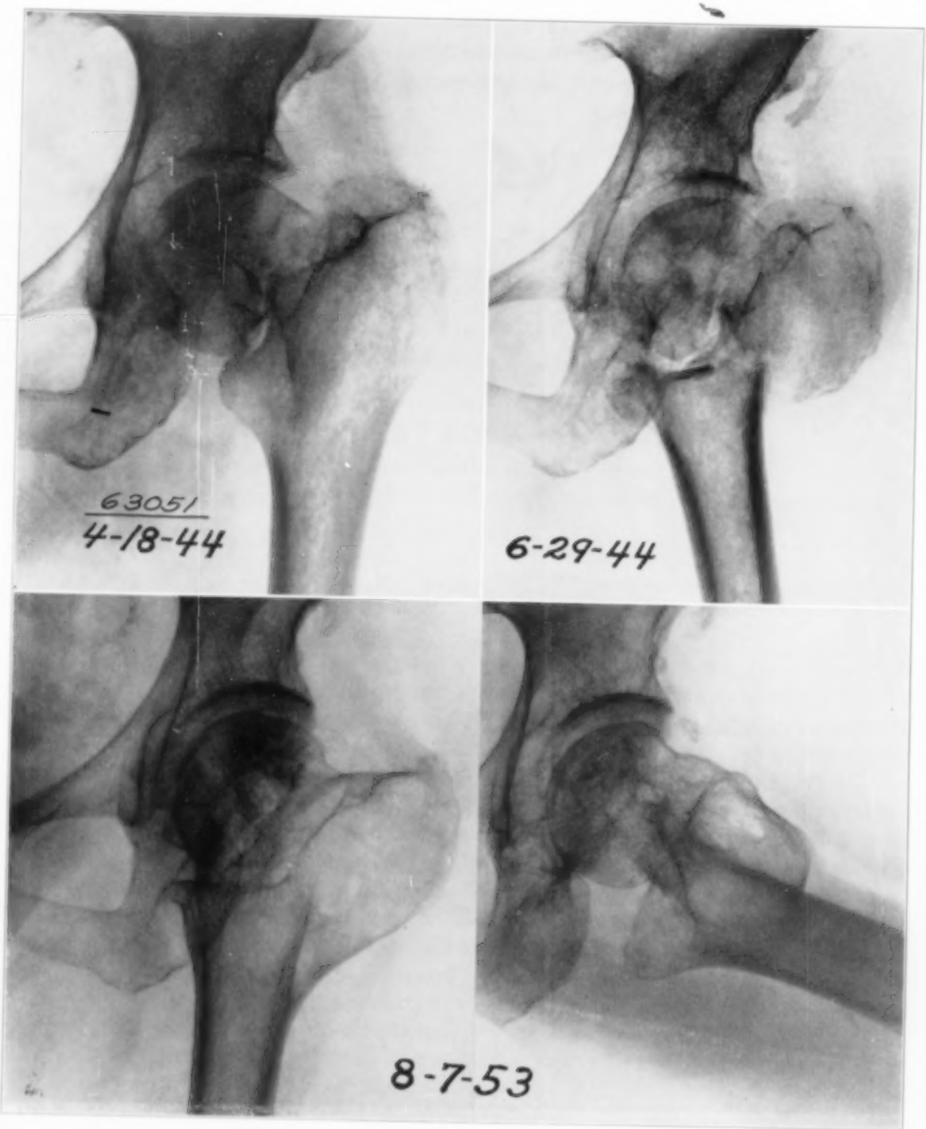


FIG. 1

*Top left.* A fracture of the femoral neck in a female, fifty-five years of age. This roentgenogram was made two and one-half months after the fracture occurred; up to that time no treatment had been applied. *Top right.* Appearance of the hip after the performance of a high-displacement osteotomy. *Bottom.* Anteroposterior and lateral roentgenograms made nine years after the operation. The result in this patient was excellent.

or preserve function of the head are definitely worth while. In pursuance of this goal, we have studied the various types of osteotomies performed at the Campbell Clinic since 1935. As Blount has stated, it is often impossible to draw a sharp line of distinction between a displacement and an angulation osteotomy, since both may be combined in one procedure. In our cases, we have considered the top of the lesser trochanter as the dividing line and have classified the osteotomies according to the level at which they were performed and also according to the degree of displacement or angulation which was predominant. For

TABLE I

AGE OF PATIENTS UPON WHOM OSTEOTOMY WAS PERFORMED
(100 Hips in Ninety-Nine Patients)

| Years | | No. of Patients |
|---|---|---|
| 15–20 | | 2 |
| 21–30 | | 2 |
| 31–40 | | 4 |
| 41–50 | 92 per cent | 12 |
| 51–60 | | 29 |
| 61–70 | | 36* |
| 71–80 | | 14 |
| 81 plus | | 1 |

* One bilateral.

TABLE II

SEX OF PATIENTS UPON WHOM OSTEOTOMY ONLY WAS PERFORMED

| Sex | No. of Patients | Per cent |
|---|---|---|
| Male | 27 | 27.3 |
| Female | 72 | 72.7 |
| Total | 99 | 100.0 |

example, a McMurray displacement osteotomy with a few degrees of angulation is regarded as a high-displacement osteotomy (Fig. 1). Figure 2 illustrates a low-angulation osteotomy of the Blount type.

Any operation for non-union of the neck of the femur should: (1) relieve pain, (2) stabilize the hip for ordinary weight-bearing, (3) allow an adequate range of motion, (4) provide reasonable freedom from avascular sclerosis and arthritis, and (5) afford promise of a hip which will endure for the normal life expectancy.

Before surgery is undertaken, the following considerations must be kept in mind: (1) the physiological age of the patient and the integrity of the regional muscles, (2) the duration of the non-union, (3) the status of the head of the femur with respect to hypertrophic changes, joint-space narrowing, and avascular sclerosis, (4) the amount of fixation of the femoral head in the acetabulum, (5) the status of the femoral neck with respect to absorption and cystic or sclerotic changes, and (6) the amount of upward displacement of the trochanter.

### *Clinical Material*

The present study includes 112 ununited fractures of the neck of the femur. In 100 hips, osteotomy was the primary procedure, while in the remaining twelve treatment was by a special innovation in which osteotomy and bone-grafting are combined. The cases will be presented in two groups.

In the follow-up of the 100 hips, seventy-seven were seen by the authors or by other members of the Campbell Clinic staff; three were followed by other doctors, who made examinations and roentgenograms according to our instructions; and twenty were followed by means of a questionnaire completed by the patient or a member of the family, and by roentgenograms which were sufficient to permit an adequate evaluation.

Twenty-three patients were followed from nine months to two years, thirty-two from two to five years, and forty-four for more than five years, the average follow-up being 6.2 years. The age, sex, and involved hip are shown in Tables I, II, and III; and the types

TABLE III

Involved Hip of Patients Upon Whom Osteotomy Only Was Performed

| Side | No. of Hips | Per cent |
|---|---|---|
| Right | 49 | 49 |
| Left | 51 | 51 |
| Total | 100 | 100 |

TABLE IV

Dates of Osteotomy Operations

| Date | High Displacement | Low Angulation | High Angulation | Low Displacement | Rotational |
|---|---|---|---|---|---|
| 1930–1935 | 1 | | | | 1 |
| 1935–1940 | 27 | 4 | 2 | 2 | |
| 1940–1945 | 21 | | 1 | | |
| 1945–1950 | 25 | 6 | 2 | | |
| 1950– | | 8 | | | |
| Total | 74 | 18 | 5 | 2 | 1 |

The average time from the occurrence of the fracture to the date of the osteotomy was 10.5 months.

of osteotomy performed are as follows: (1) high-displacement osteotomy, performed upon seventy-four patients, (2) low-angulation osteotomy, performed upon eighteen patients, (3) high-angulation osteotomy, performed upon five patients, (4) low-displacement osteotomy, performed upon two patients, and (5) intertrochanteric rotational osteotomy, performed upon one patient.

Although 100 osteotomies were performed, there were only ninety-nine patients, one having bilateral fractures. One patient, in the high-displacement-osteotomy group, died three days after the operation, which left ninety-nine hips available for study.

It will be noted in Table IV that there was a trend of preference from the high-displacement to the low-angulation operation. The average length of time from the date of the fracture of the femoral neck until the time of the osteotomy was 10.5 months.

### *Results*

In evaluating the results, we have combined the clinical or functional result with the roentgenographic findings. An *excellent* result was characterized by union of the fragments at both the osteotomy site and the fracture site, a painless range of motion of at least 75 per cent of the normal, a negative Trendelenburg sign, less than one-half inch of shortening, no limp, sufficient endurance for ordinary activity, and no roentgenographic evidence of avascular necrosis or of hypertrophic changes.

The result was regarded as *good* when both the fracture and the osteotomy fragments united; when there was no appreciable pain, no more than minimal limp after a long day of strenuous activity, at least 75 per cent of the normal range of motion, only a slightly positive Trendelenburg sign, and less than one inch of shortening; when the functional result was satisfactory during eight hours of activity; and when there was no roentgenographic evidence of avascular necrosis, although minimal hypertrophic changes with minimal joint-space narrowing might be present.

A *fair* result was characterized by mild to moderate pain, a mildly positive Trendelenburg sign, a moderate limp, a range of motion of from 25 to 50 per cent of the normal, union of the osteotomy fragments but possible persistent non-union of the fracture,

TABLE V

FINAL RESULTS AFTER OSTEOTOMY ALONE

| Type of Osteotomy | Excellent and Good | Fair and Poor | Favorable Results (*Per cent*) |
|---|---|---|---|
| High Displacement | 24 | 49 | 33 |
| Low Angulation | 12 | 6 | 67 |
| Low Displacement | 2 | 3 | 40 |
| High Angulation | 0 | 2 | 0 |
| Rotational | 1 | 0 | 100 |
| Total | 39 | 60 | 39 |

TABLE VI

INCIDENCE OF UNION OF THE FRACTURES

| Type of Osteotomy | Union | Non-Union | Favorable Results (*Per cent*) |
|---|---|---|---|
| High Displacement | 34 | 39 | 47 |
| Low Angulation | 16 | 2 | 89 |
| High Angulation | 2 | 3 | 40 |
| Low Displacement | 1 | 1 | 50 |
| Rotational | 1 | 0 | 100 |
| Total | 51 | 45 | 55 |

moderate hypertrophic changes with joint-space narrowing, possible increased sclerosis of the femoral head, and restricted function of the hip.

A *poor* result revealed considerable pain, marked limp, more than 50 per cent limitation of motion or gross instability, inability to engage in an occupation requiring walking or standing, confinement to crutches or a wheel chair, and roentgenographic evidence of advanced hypertrophic changes, avascular necrosis, marked joint-space narrowing, persistent non-union of the fracture, and, in two cases, non-union of the fragments at the osteotomy site. The final results are shown in Table V.

*Union:* Non-union of the fragments occurred after only two osteotomies, both of the high-displacement type; in the remainder union occurred between the second and third months. The fractures of the neck which united did so, as a rule, between the fourth and sixth months. Table VI shows the incidence of union of the fractures.

*Internal fixation:* Internal fixation had a more favorable effect upon the general condition of the patient than upon the condition of the hip. Metallic fixation eliminates the necessity for casts, braces, and splints and allows the patient out of bed in a few days. Early activity establishes good tissue turgor and muscle tone; also, a normal nitrogen balance is more easily maintained, decreasing the danger of general debility and decubitus ulcers.

Too few high-angulation, low-displacement, or rotational osteotomies were performed for the results of these operations to be of significance. (A rotational intertrochanteric osteotomy was produced inadvertently during a blind osteotomy and manipulation in 1935. The good result was both surprising and gratifying.) In Table VII, these three types of operations are omitted.

*Arthritis:* Hypertrophic changes in the hip were diagnosed by roentgenographic demonstration of osteophytes, of sclerosis, and of joint-space narrowing indicative of articulate cartilage degeneration (Table VII).

TABLE VII

RESULTS AFTER OSTEOTOMY ALONE

| Type of Osteotomy | | | Favorable Results (*Per cent*) |
|---|---|---|---|
| | Pain | | |
| | No Pain | Pain | |
| High Displacement | 49 | 21 | 70 |
| Low Angulation | 16 | 2 | 89 |
| | Shortening of the Extremity | | |
| | Less than One Inch | More than One Inch | |
| High Displacement | 22 | 40 | 35 |
| Low Angulation | 15 | 2 | 88 |
| | Limp | | |
| | Negative | Positive | |
| High Displacement | 28 | 44 | 39 |
| Low Angulation | 15 | 3 | 83 |
| | Trendelenburg Test | | |
| | Negative | Positive | |
| High Displacement | 24 | 36 | 40 |
| Low Angulation | 12 | 4 | 75 |
| | Range of Motion | | |
| | More than 50 Per cent | Less than 50 Per cent | |
| High Displacement | 25 | 41 | 38 |
| Low Angulation | 13 | 5 | 72 |
| | Endurance | | |
| | Excellent or Good | Fair or Poor | |
| High Displacement | 28 | 44 | 39 |
| Low Angulation | 10 | 8 | 56 |
| | Hypertrophic Changes | | |
| | Absent or Minimal | Present | |
| High Displacement | 20 | 41 | 33 |
| Low Angulation | 7 | 9 | 44 |
| | Necrosis | | |
| | No Necrosis | Necrosis | |
| High Displacement | 29 | 37 | 44 |
| Low Angulation | 10 | 7 | 59 |

*Avascular sclerosis:* Avascular sclerosis was present to a slight degree prior to operation in only a few patients of this series. When sclerosis was present initially, some other type of operation was usually performed. For the past several years, most of these patients, if in the older age group, have been fitted with hip prosthesis.

The degree or amount of avascular sclerosis observed after the operation (Table VII) has varied from demarcation or impending infarction to fragmentation and breaking up of the head.

## OSTEOTOMY AND BONE-GRAFTING

In our attempt to preserve circulation in the head of the femur or to restore it to the extent that advanced degenerative arthritic changes and avascular necrosis would not develop, we based our approach on the stimulating works of Phemister, Dickson, and Brittain. With these works in mind, one of the authors (M. J. S.) during the past four years has performed twelve operations combining osteotomy with bone-grafting and internal fixation.* This procedure embodies the following established principles: (1) Osteotomy can be used to correct the faulty mechanics caused by the hip being in the varus position; by osteotomy, the rotational and shearing forces at the fracture site are converted into impacting forces. (We attempted to make this correction with the high-displacement type of osteotomy at first, but we now believe that the osteotomy of choice is the low-angulation procedure.) (2) Sufficient internal fixation eliminates the necessity of plaster-of-Paris or of any form of external support. (3) Cortical-bone grafts, extending from the osteotomy site across the neck into the central or lower part of the head of the femur, give the best results. This procedure, we believe, hastens the development of a new channel of blood to the capital portion of the femur.

Brittain's ischiofemoral fusion for tuberculosis of the hip demonstrated that a graft, when placed through the site of the subtrochanteric osteotomy, lies in a rich vascular bed and is rapidly incorporated in the healing process. Our experience, as well as that of other observers, shows that the fragments resulting from a subtrochanteric osteotomy will unite in approximately two months, indicating that nature rapidly mobilizes the osteogenic properties in this rich vascular area.

At first, we agreed with Phemister that the graft should be applied to the superior weight-bearing portion of the head in order to support the potential area of infarction until revascularization was complete. After reviewing our cases, however, we are convinced that the graft should not be applied to this area. Since the superior portion may have a disturbed blood supply and since it is the area of maximum weight-bearing, revascularization of the graft at this point is difficult. Furthermore, metal or any object passing through the superior lateral portion of the head may sever the majority of the vessels supplying the epiphyseal area. The patients in whom we have observed mild impending infarcts are those in whom the grafts were placed in the superior weight-bearing area of the head. Therefore, we now insert the grafts into the central or lower half of the capital portion.

We have used internal fixation to eliminate the need for prolonged immobilization. This allows the patients to be up in a chair by the second or third day after the operation. After two to three weeks, they may return home, and after two months they are permitted up on crutches. No weight-bearing is allowed on the operated extremity for four to six months.

The question continually arises: "Will a cortical graft carry blood into the head?" Since most cells in cortical-bone grafts, particularly in grafts of bone-bank bone, are certainly dead, the useful aspect of the graft is the structural framework it provides. If a hole is left in the patient's bone, it will invariably fill with a well-differentiated, fibrous connective tissue which remains as dense scar, and if converted into bone requires a prolonged period of time. The cortical grafts tend to hold this channel open and to supply the framework through which the area can be revascularized. When the grafts lose their identity on the roentgenogram, they at least serve as an indicator that a new channel of blood has entered the area.

### *Technique*

In the presence of long-standing non-union with shortening of the leg, it may be necessary to apply sufficient preliminary traction to correct the proximal displacement of the trochanter and shaft.

At operation, the patient is placed on the table in such a position that anteroposterior and lateral roentgenograms may be made at any time. The supporting foot-piece should

---

* Since the date of writing, six additional operations have been performed, making a total of eighteen operations. Sixteen of the eighteen patients are now walking without crutches, braces, or support.

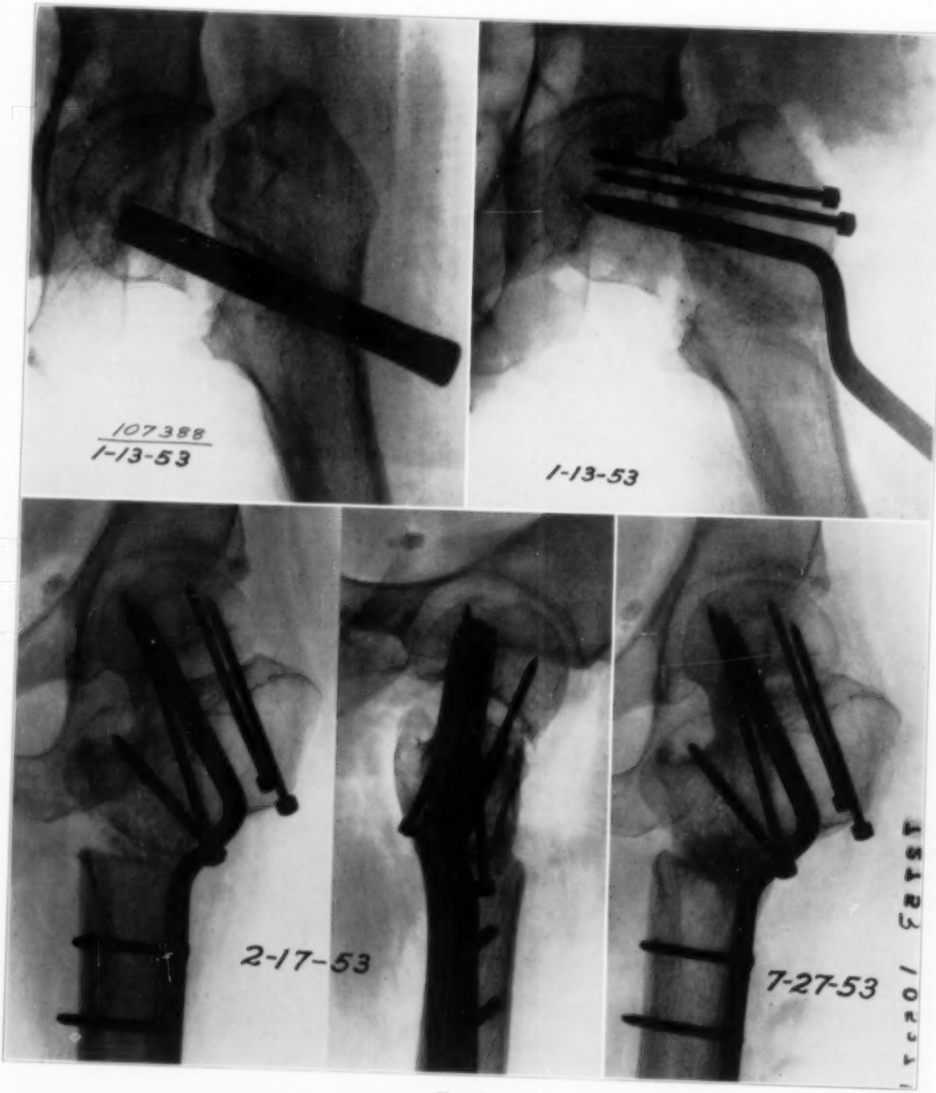


FIG. 2

*Top left.* Fracture of the femoral neck in a male, fifty-one years of age. This fracture was originally treated by insertion of a Smith-Petersen nail. After twelve months, non-union was still present and the nail was partially extruded. *Top right and bottom left.* Appearance of the hip after the performance of a low-angulation osteotomy. *Bottom center and right.* Final anteroposterior and lateral roentgenograms. Fixation of the hip has been obtained by the Blount-Moe technique.

be sterile, so that manipulation may be accomplished by the surgeon when necessary (Fig. 3).

A lateral incision is made, similar to that used in nailing an intertrochanteric fracture. The proximal lateral portion of the femoral shaft is exposed subperiosteally for about six inches from the level of the tubercle of the trochanter. Any previously inserted pins or screws are removed. A guide wire is then passed from the level of the lower border of the lesser trochanter into the central or lower portion of the head of the femur. Roentgenograms are made in two planes to check the position and depth of the wire. A Henderson reamer

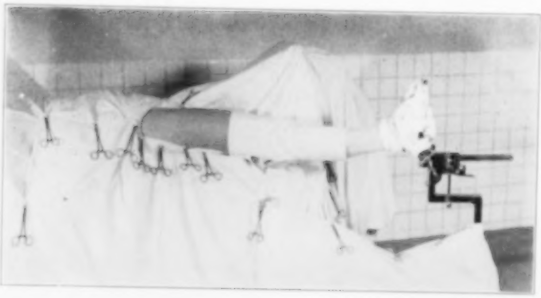


FIG. 3

Fig. 3: The limb has been draped. A sterile stirrup and foot-piece are being used in order that the surgeon may manipulate the hip at any time.

Fig. 4: *A*. A six-hole stainless-steel plate. *B*. The top of the plate has been removed at *x*, and a new hole has been drilled at *y*. *C*. The plate has been bent in such a way that it may be used in a hip treated by a low-angulation osteotomy.

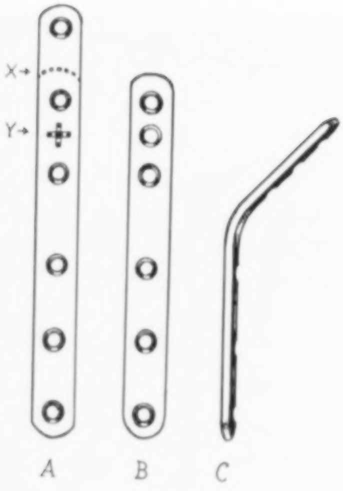


FIG. 4

with a diameter of eleven millimeters is threaded over the wire and inserted to within one centimeter of the periphery of the head. If the head shows sclerosis, a long-handled curette is passed through the reamer hole, and by rotation of the curette, a considerable amount of sclerotic bone may be removed.

Pencil cortical grafts are prepared from tibial bone, either autogenous or homogenous, and are inserted into the reamed hole until the hole is filled. The cervical fragments are thus held fairly securely as the operation proceeds. With a reciprocating saw, an osteotomy is performed at the level of the distal end of the grafts. A wedge of bone is removed or a Blount type of angulation is done to effect 25 to 30 degrees of valgus beyond the normal 135-degree angle of the neck. The foot-piece and leg being sterile, the limb is easily manipulated and fixed in the new position.

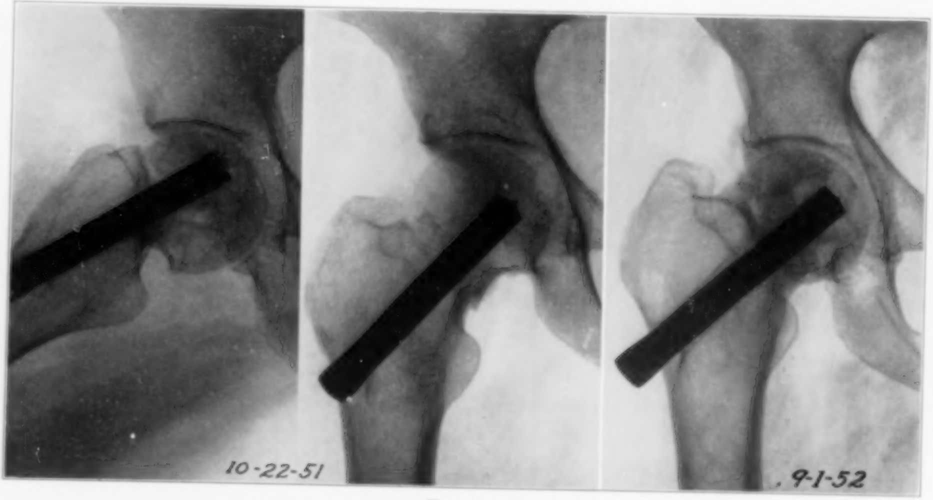


FIG. 5-A

*Left and center*. Lateral and anteroposterior roentgenograms. The fresh femoral-neck fracture in this patient (forty-two years of age) was treated by insertion of a Smith-Petersen nail. *Right*. Roentgenogram made twelve months after the operation. The original fracture has united, but a pathological fracture has begun to develop at the base of the head. Sclerosis is present in the head.

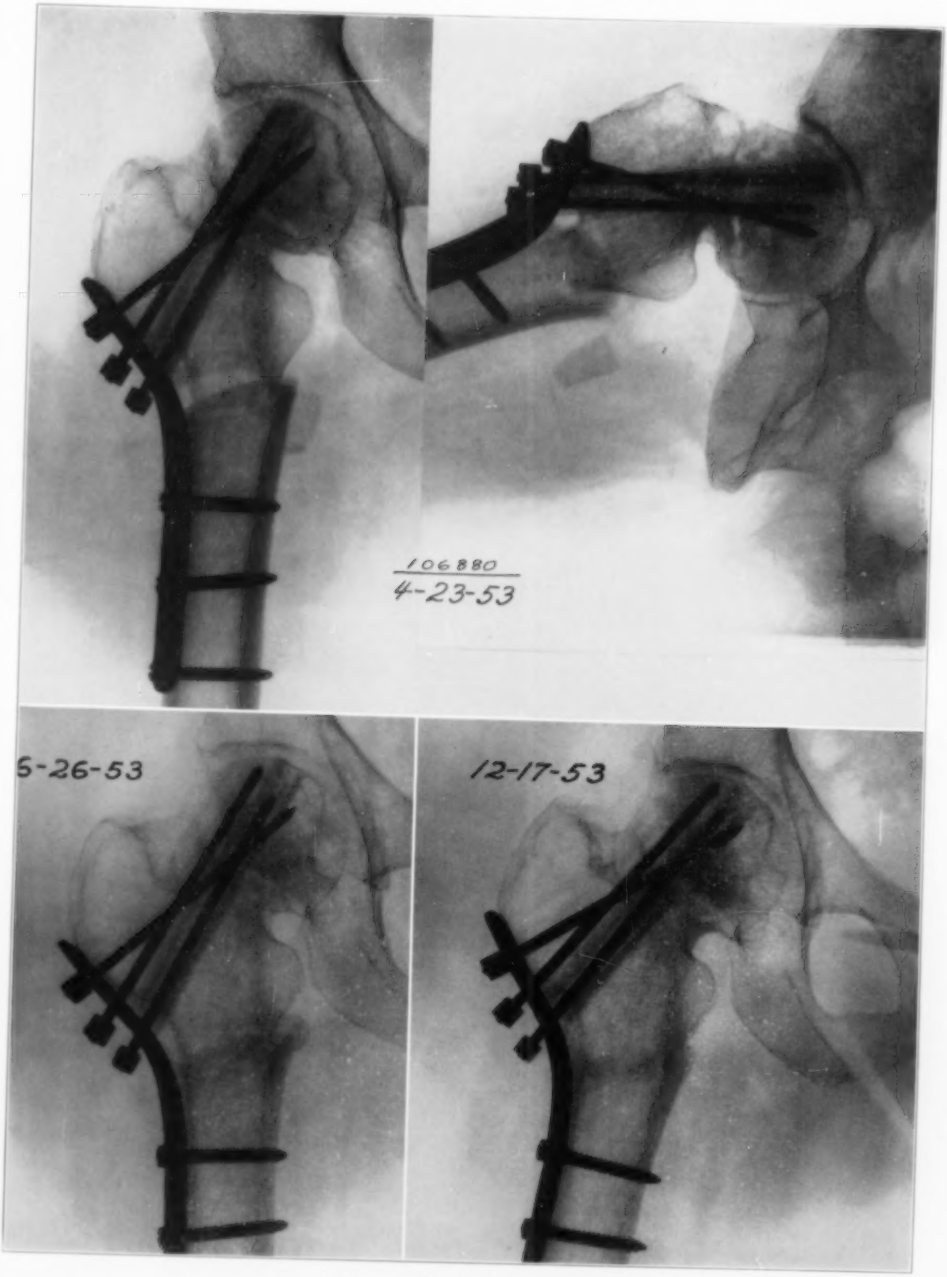


Fig. 5-B

*Top.* Nineteen months after the occurrence of the fracture, a low-angulation osteotomy was performed. In this operation a lateral wedge of bone was removed and fixation was obtained by the attachment of a revised six-hole plate (three Knowles pins and three screws being used) and by the insertion of four cortical pencil bone grafts. The grafts extend from the osteotomy site up into the head. *Bottom left.* Anteroposterior roentgenogram made two months after the operation. The osteotomy fragments are solid. *Bottom right.* Anteroposterior roentgenogram made eight months after the operation. The osteotomy fragments and pathological fracture are solid and the joint space has been maintained. The patient is able to walk without support.

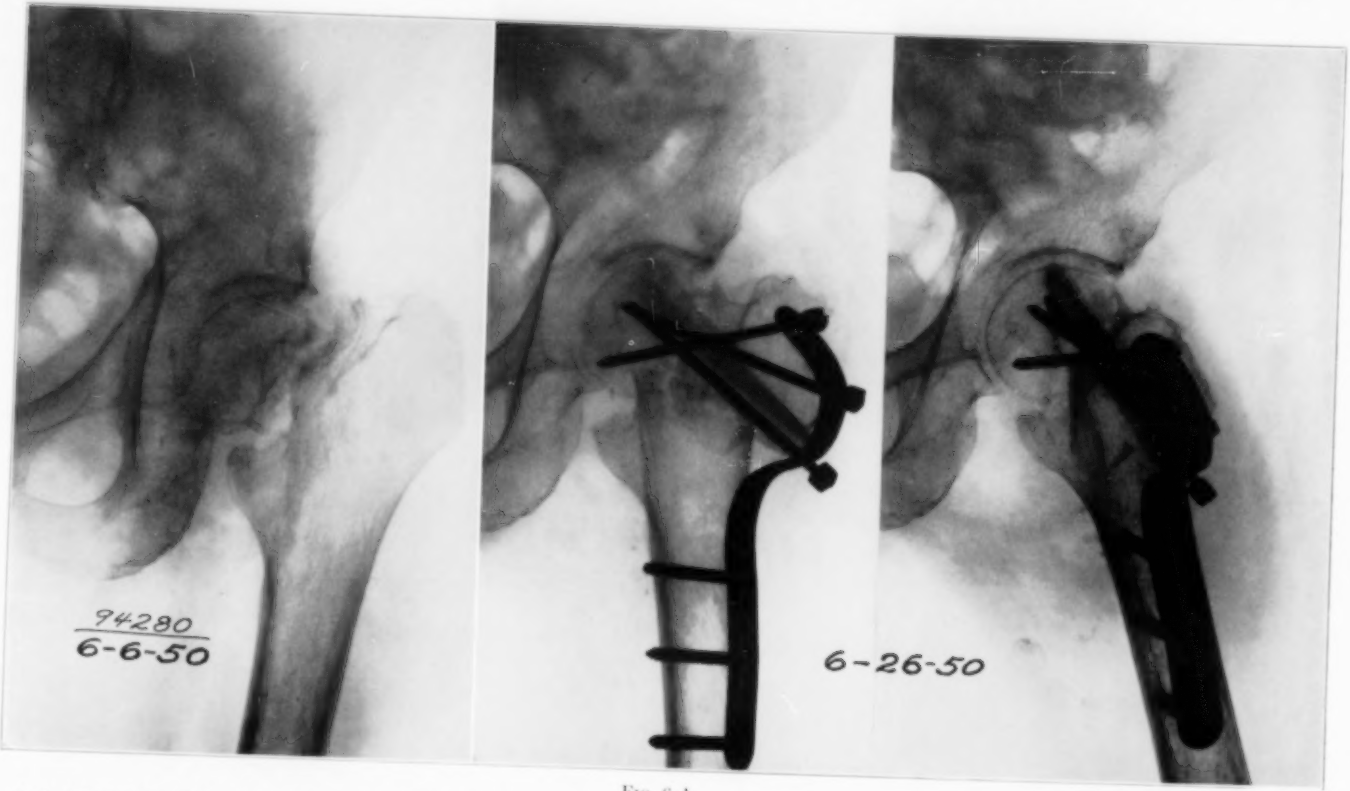


Fig. 6-A

*Left.* A femoral-neck fracture of nine months' duration in a female, seventy-nine years of age. Treatment has been by bed rest alone. *Center and right.* Appearance of the hip after the performance of a high-displacement osteotomy. A six-hole stainless-steel plate has been bent and fixed to the hip by means of three Knowles pins and three screws. Four pencil cortical grafts have been inserted. These grafts extend from the osteotomy site up into the head.

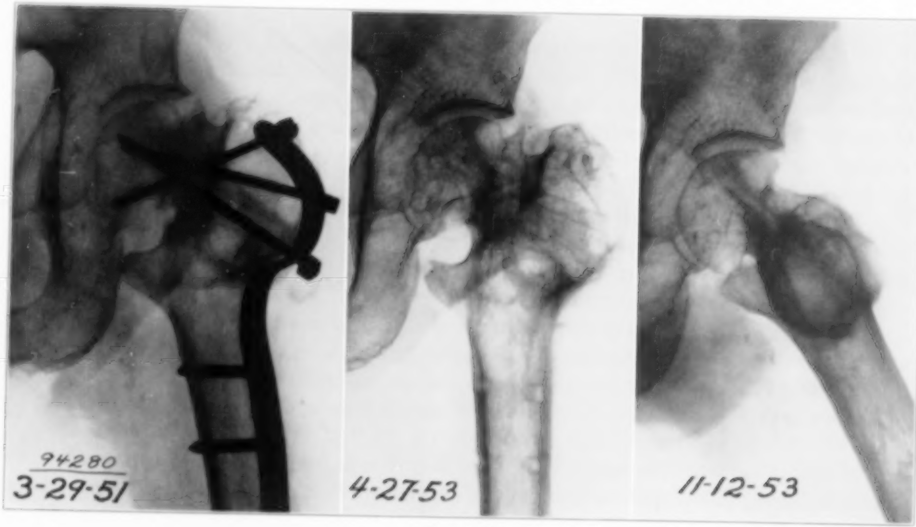


FIG. 6-B

A roentgenogram made nine months after the operation (*left*) and two roentgenograms made about three years after the operation. The fracture and the fragments at the osteotomy site have united solidly, the grafts have lost their identity, the head is viable, and the joint space has been maintained. The patient walks without support or pain. The result in this case is good.

A six-hole SMo stainless-steel plate, previously prepared by the removal of the segment with the top hole and by the drilling of a hole between the second and third holes, is bent to the desired angle (Fig. 4). The plate is fixed to the lateral surface of the femur by three screws and to the trochanter and head by three Knowles pins (Fig. 5-B).

Final roentgenograms are made before closure of the incision. No splint or cast is necessary.

### *Clinical Material*

Twelve osteotomy and bone-grafting operations have been performed for non-union of the femoral neck in adults. The ages of the patients ranged from forty-two to seventy-nine, the average being sixty. There have been no deaths to date. There were ten females and two males, and in nine patients the left hip was involved and in three, the right.

All of the group were followed by the authors. Two have been operated upon within the past year, one six months and the other ten months ago. The longest period of follow-up was forty-eight months, the average being twenty-seven months. The average length of time which elapsed between the original injury and the osteotomy and bone-grafting was 10.7 months.

Four of the osteotomies, all performed more than three years ago, were of the high-displacement type; the remainder were low-angulation procedures. We have used cortical pencil grafts, ten tibial, one fibular, and one rib. Eleven of these grafts were homogenous and were from the bone bank; one of the tibial grafts was autogenous.

### *Results*

In analyzing the results obtained in these operations, we used the same general plan of study which we followed in reviewing the results obtained in the patients treated by osteotomy alone.

*Union:* All of the osteotomy fragments and neck fractures united. The shortest time required for union of the fragments at the osteotomy site was two months, the longest three months. The shortest period required for union of the fracture was three months, the longest eleven months, the average being 5.1 months.

We reviewed the state of revascularization of the graft and attempted to determine the time required for the graft to lose its sharp line of demarcation, this loss being considered an indication of at least partial revascularization (Figs. 6-A and 6-B). For nine patients, the shortest time recorded was four months and the longest fourteen months, the average being nine months. In the remaining three patients the lines of the graft have not yet lost their identity.

*Pain:* Nine patients are completely free of pain and two have slight pain. One has moderate pain, and the result in this patient is regarded as fair, although he walks with a cane and does not require crutches. This man began full weight-bearing after two months, despite instructions to the contrary.

*Shortening:* Among the twelve patients operated upon, one has no shortening of the extremity, nine have a shortening of less than a half inch, one had a shortening of three-quarters of an inch, and one has a shortening of one and a quarter inches. Thus, in eleven patients the shortening is less than one inch, and in nine of these it is less than a half an inch.

*Range of motion:* The range of motion of the hips was estimated to be as follows. Seven patients have 75 per cent or more of normal motion, three have more than 50 per cent but less than 75 per cent, and two have more than 25 per cent but less than 50 per cent of normal motion.

*Degenerative changes:* Arthritic changes were diagnosed according to roentgenographic findings of osteophytes, sclerosis, and joint-space narrowing. Four of the twelve patients have mild arthritic changes and the others have slight changes or none.

*Avascular sclerosis:* Seven of the patients had moderate to marked avascular sclerosis of the head prior to operation. Three of the seven have exhibited no change, while four have shown definite improvement. One patient who had marked sclerosis now has only slight sclerosis. The remaining five patients had no sclerosis before the operation; in three of these the bone structure has remained normal, while in one there is a slight increase in the density of the head and in another there is a marked increase. The last patient is the man who walked two months after the operation; the head of the femur disintegrated and it and the neck are now malformed and shortened.

These results are tabulated in Table VIII.

## DISCUSSION

A review of the series of 100 ununited fractures of the neck of the femur treated by osteotomy shows an evolution in treatment from high-displacement to low-angulation osteotomy and from postoperative plaster immobilization to internal fixation.

Rapid union of the bone fragments following a trochanteric osteotomy (within two to three months) suggests that the operation is performed at the site of a rich vascular supply, probably near the cruciate anastomosis. Osteotomy has facilitated union of the fracture of the neck in a substantial number of cases, although not in a sufficient number to justify reliance upon this procedure alone to stimulate union and prevent degenerative changes.

The relief of pain following osteotomy is encouraging. The procedure is seldom warranted, however, unless it can accomplish more than mere relief of pain.

In patients with ununited fractures, the initial shortening of the leg should be overcome by preliminary traction, and one should not be content with an operation which will result in more than one inch of shortening. The trochanter should be placed so as to insure normal, or essentially normal, leverage for the gluteal muscles. Even though a majority of patients are beyond fifty years of age, they are entitled to a normal life expectancy with a hip compatible with their physiological age.

Necrosis in the femoral head and degenerative changes, the chief disabling factors, are basically the result of disturbed circulation. Undoubtedly, molecular changes in the

TABLE VIII

PRELIMINARY RESULTS OF OSTEOTOMY WITH BONE-GRAFTING IN TWELVE PATIENTS

| Result | None | Minimum | Moderate | Marked |
|---|---|---|---|---|
| Pain | 9 | 2 | 1 | |
| Shortening of the leg | 1 | 9 | 2 | |
| Impaired range of motion | | 7 | 3 | 2 |
| Hypertrophic changes | 8 | | 4 | |
| Avascular sclerosis | 7 | | 5 | |

bone or crystallization or thrombosis play a part in producing these changes. As pointed out by Trueta and Harrison, the development of avascular sclerosis and arthritis may be strongly influenced by thrombosis in the blood sinusoids, as a result of anaemia or poor generalized circulation, shock, and general debility.

We agree with Phemister that a period of non-weight-bearing of up to two years would probably be advantageous, but it is not practical. Unless the procedure enables the patient to begin weight-bearing at approximately six months, it cannot long withstand the competition of other types of reconstructive surgery, even though the final result which it produces is more likely to approach the normal hip than is the result following any of the reconstruction operations or following the insertion of a prosthesis.

Non-union, although a paramount problem following fracture of the neck of the femur, is often no more disabling than a semi-necrotic head and degenerative changes. In any attempt to combat these three crippling conditions, the primary requisite is the reestablishment of the blood supply. We believe that the combination of osteotomy (to correct any faulty mechanics of the fractured neck) with internal fixation (to eliminate the necessity for external immobilization) and bone-grafting, extending from the rich subtrochanteric vascular bed, across the femoral neck into the head (to stimulate revascularization), offers a good chance of providing the best functional hip.

The twelve cases in which the osteotomy and bone-grafting operation was employed are presented as a preliminary report. The final results cannot be determined at this time, although the results of the procedure thus far are encouraging.

## REFERENCES

1. BARTON, J. R.: On the Treatment of Anchylosis by the Formation of Artificial Joints. North Am. Med. and Surg. J., **3:** 279–400, 1827.
2. BATCHELOR, J. S.: Excision of the Femoral Head and Neck in Cases of Ankylosis and Osteoarthritis of the Hips. Proc. Roy. Soc. Med., **38:** 689–690, 1945.
3. BLOUNT, W. P.: Blade-Plate Internal Fixation for High Femoral Osteotomies. J. Bone and Joint Surg., **25:** 319–339, Apr. 1943.
4. BLOUNT, W. P.: Proximal Osteotomies of the Femur. *In* Instructional Course Lectures, The American Academy of Orthopaedic Surgeons, 1952. Vol. 9, pp. 1–29. Ann Arbor, J. W. Edwards, 1952.
5. BOYD, H. B., and GEORGE, I. L.: Fractures of the Hip. Results Following Treatment. J. Am. Med. Assn., **137:** 1196–1199, 1948.
6. CLEVELAND, MATHER; BOSWORTH, D. M.; and DELLA PIETRA, A.: Subtrochanteric Osteotomy and Spline Fixation for Certain Disabilities of the Hip Joint. J. Bone and Joint Surg., **33-A:** 351–361, Apr. 1951.
7. COLONNA, P. C.: A New Type of Reconstruction Operation for Old Ununited Fracture of the Neck of the Femur. J. Bone and Joint Surg., **17:** 110–122, Jan. 1935.
8. COLONNA, P. C.: A Reconstruction Operation for Old Ununited Fracture of the Femoral Neck. J. Bone and Joint Surg., **19:** 945–954, Oct. 1937.
9. DICKSON, J. A.: The High Geometric Osteotomy, with Rotation and Bone Graft, for Ununited Fractures of the Neck of the Femur. J. Bone and Joint Surg., **29:** 1005–1018, Oct. 1947.
10. DICKSON, J. A.: Treatment of Ununited Fractures of the Neck of the Femur. J. Am. Med. Assn., **137:** 1199–1209, 1948.
11. DICKSON, J. A.: The "Unsolved Fracture." A Protest Against Defeatism. J. Bone and Joint Surg., **35-A:** 805–822, Oct. 1953.

12. Haas, Julius: Zur Technik der Lorenzschen Bifurkation (Die schraeg frontale Osteotomie). Zeitschr. f. Orthop. Chir., **43:** 481–491, 1924.
13. Henderson, M. S.: Ununited Fracture of the Neck of the Femur Treated by the Aid of the Bone Graft. J. Bone and Joint Surg., **22:** 97–106, Jan. 1940.
14. Linton, P.: On Different Types of Intracapsular Fractures of the Femoral Neck. Surgical Investigation of Origin, Treatment, Prognosis and Complications in 365 Cases. Acta Chir. Scandinavica, **93:** 1–22, 1944.
15. Luck, J. V.: A Reconstruction Operation for Pseudarthrosis and Resorption of the Neck of the Femur. J. Iowa State Med. Soc., **28:** 620–622, 1938.
16. McMurray, T. P.: Ununited Fractures of the Neck of the Femur. J. Bone and Joint Surg., **18:** 319–327, Apr. 1936.
17. McMurray, T. P.: Osteo-Arthritis of the Hip Joint. J. Bone and Joint Surg., **21:** 1–11, Jan. 1939.
18. Magnuson, P. B.: The Repair of Ununited Fracture of the Neck of the Femur. J. Am. Med. Assn., **98:** 1791–1794, 1932.
19. Milch, Henry: The "Pelvic Support" Osteotomy. J. Bone and Joint Surg., **23:** 581–595, July 1941.
20. Milch, Henry: The Resection-Angulation Operation for Arthritis and Ankylosis of the Hip. J. Internat. Coll. Surg., **13:** 750–753, 1950.
21. Pauwels, Friedrich: Der Schenkelhalsbruch. Ein mechanisches Problem. Stuttgart, Ferdinand Enke, 1935.
22. Phemister, D. B.: Treatment of the Necrotic Head of the Femur in Adults. J. Bone and Joint Surg., **31-A:** 55–66, Jan. 1949.
23. Reich, R. S.: Ununited Fracture of the Neck of the Femur Treated by High Oblique Osteotomy. J. Bone and Joint Surg., **23:** 141–158, Jan. 1941.
24. Santos, J. V.: Changes in the Head of the Femur after Complete Intracapsular Fracture of the Neck. Their Bearing on Nonunion and Treatment. Arch. Surg., **21:** 470–530, 1930.
25. Schanz, A.: Zur Behandlung der veralteten angeborenen Hüftverrenkung. Münchener Med. Wochenschr., **69:** 930–931, 1922.
26. Schanz, A.: Uber die nach Schnelhalsbrüchen zurückbleibenden Gehstörungen. Deutsche Med. Wochensehr., **51:** 730–732, 1925.
27. Schumm, H. C.: The Schanz Osteotomy for Fractures of the Neck of the Femur. J. Bone and Joint Surg., **19:** 955–963, Oct. 1937.
29. Trueta, J., and Harrison, M. H. M.: The Normal Vascular Anatomy of the Femoral Head in Adult Man. J. Bone and Joint Surg., **35-B:** 442–461, Aug. 1953.
30. Wilson, P. D.: Trochanteric Arthroplasty in the Treatment of Ununited Fractures of the Neck of the Femur. J. Bone and Joint Surg., **29:** 313–327, Apr. 1947.
31. Wolcott, W. E.: Circulation of the Head and Neck of the Femur. Its Relation to Nonunion in Fractures of the Femoral Neck. J. Am. Med. Assn., **100:** 27–34, 1933.

## DISCUSSION

Dr. J. A. Dickson, Cleveland, Ohio: Dr. Stewart and Dr. Wells have come to the same conclusion that I have reached concerning the best treatment for non-union following fracture of the femoral neck. Osteotomy (to correct the shearing stresses at the fracture site) combined with internal fixation and bone-grafting (to stimulate revascularization and creeping substitution of the head) offers an excellent means of procuring a normal functioning hip. This is particularly true if the ununited fracture is treated relatively early. The authors and I have utilized the same basic approach, which is to convert the high-angle fracture to a low-angle fracture by means of an osteotomy. Their wedge osteotomy, however, does not procure equalization of limb length as accurately as does the rotation osteotomy which I employ. It would seem that the multiple pins that they insert across the fracture site at varying angles in order to obtain fixation might have certain disadvantages, including interference with impaction; the authors' results do not bear out this supposition, however.

Although grafting procedures have not been as extensively used as osteotomies in the treatment of ununited fractures of the femoral neck, I am sure they are most important. I agree with the authors that the chief virtue of the cortical graft is that it forms a framework for revascularization, but I am convinced that this advantage can be more readily obtained with the use of cancellous bone. The authors stated that they found that the graft should be placed in the central portion of the head and also suggested that it is well to curette the superior weight-bearing portion of the head. I concur in this idea but feel that instead of using cortical bone across the fracture at one place, there is a definite advantage in making a window in the trochanteric segment, which allows complete removal of the scar tissue from the fracture site, and in packing the neck and the curetted portion of the head with cancellous bone. This assures that there will be a direct pathway from the trochanteric segment to the head, a pathway which may be rapidly vascularized and along which revascularization and creeping substitution may be stimulated. The window may be as wide as necessary to remove all the scar tissue from the fracture site and the cancellous bone may be extended as far as is indicated. After the grafts are inserted, the window is replaced into the neck of the femur so that the shape of the neck is practically normal. The conclusions of Dr. Stewart and Dr. Wells will, I am sure, stimulate many to strive for better results in treating ununited femoral-neck fractures.

Dr. Paul C. Colonna, Philadelphia, Pennsylvania: The authors have really presented two papers in one; first, they have presented a splendid review of the results obtained in 100 ununited femoral-neck fractures treated by various types of osteotomy; and, second, they have presented the results obtained in twelve fractures treated by combined osteotomy and bone-grafting.

In the first paragraph of their paper, they refer to "the recently popularized hip prosthesis." I believe that the cases in which this prosthesis is used are now much more carefully selected than they were previously and that there is an over-all lack of enthusiasm among orthopaedic surgeons for this method of treatment. This, I hope, means that the hip prosthesis will be more constructively and selectively employed than it has been heretofore.

Preoperative findings provide essential information for evaluating operative results. The decision as to whether the head of the femur can or cannot be salvaged is very important, and to date this decision has been generally based upon the preoperative roentgenographic appearance of the head. Probably some day we will have better methods for the early determination of beginning avascular necrosis. Patients who have no necrosis before the operation and those who have marked absorption and necrosis present no problem of decision for the surgeon; those who have moderate necrosis before the operation do present a problem.

It is of interest that 45 per cent of the patients in the authors' series showed persistent non-union of the femoral neck following osteotomy. Although union of the fragments at the osteotomy site was not materially affected by the type of osteotomy used (high, low, displaced, angulated), union of the femoral-neck fracture was affected. In general, the low osteotomy resulted in a much higher percentage of union of the fracture than did any other type of osteotomy; the authors have not performed the high osteotomy during the past four years.

Fifty per cent of the original 100 osteotomies resulted in a leg shortening of one inch or more. This figure may not be complete, however, for in thirteen cases the postoperative shortening was not recorded. A shortening of one inch is not a tragic complication, but it is certainly not a desirable feature and may be considerably lessened by the use of the geometric osteotomy of Dickson or the trochanteric reconstruction operation [Colonna].

In the second part of their paper the authors introduce a possible solution to a very difficult problem, preserving or restoring the viability of the head. In the twelve patients upon whom the authors performed the low-osteotomy and cortical-bone-grafting operation (with the graft well placed in the central portion of the head), the results appeared very encouraging. I would favor autogenous over homogenous cortical grafts, however.

Dr. Stewart (closing): Dr. Dickson's work has been a great stimulus to us for many years. The principle behind his operation for non-union (osteotomy and bone-grafting) is essentially the same as the principle of ours. Only the technique varies, with the more important variations being the necessity in our procedure for only one incision (a lateral one), and the utilization in our procedure of multiple cortical grafts extending from the osteotomy site across the neck and into the central portion of the head.

It may be true, as Dr. Colonna has suggested, that the hip prosthesis is less popular now than it has been, but certainly a few years ago at the Academy Meeting its increasing popularity was quite apparent.

In connection with Dr. Colonna's remarks concerning the importance of preoperative findings, I would like to point out that it has been our general policy not to perform osteotomies upon patients who show avascular necrosis of the femoral head. In these patients we have performed various types of reconstruction procedures, sometimes, for example, using the Colonna operation.

In some of the twelve patients upon whom osteotomy combined with bone-grafting was performed, however, sclerosis of the femoral head was definitely present before the operation. We feel the operation of osteotomy and bone-grafting may be a good intermediate procedure to use upon patients in whom the femoral head is neither viable nor extremely sclerotic. Patients with non-union of several months' duration or patients who are beginning to show some increased density in the femoral head require more than just an osteotomy, and we believe that bone-grafting, as described here, will add the needed extra impetus. In the young individual especially, we think an effort should be made to restore the patient's femoral head and neck to normal. We offer this review of twelve cases as a preliminary report.

# POSTERIOR ARTHRODESIS OF THE ANKLE AND SUBTALAR JOINTS *

BY O. SHERWIN STAPLES, M.D., HANOVER, NEW HAMPSHIRE

*From the Orthopaedic Service of the Mary Hitchcock Memorial Hospital, Hanover, New Hampshire, and the Veterans Administration Hospital, White River Junction, Vermont*

There are many ways to fuse an ankle joint. In addition to the time-honored anterior approach for fusion, a variety of lateral, medial, central, and posterior approaches have been described[1-8]. Each has its good points and its indications, and the assortment provided gives the surgeon a fairly wide selection from which to choose that method most suitable for the individual problem. The purpose of this paper is (1) to present a method of posterior fusion of the ankle, modifying Campbell's technique, (2) to outline the advantages and disadvantages of this method, and (3) to re-emphasize the usefulness of a posterior method of fusion in selected cases.

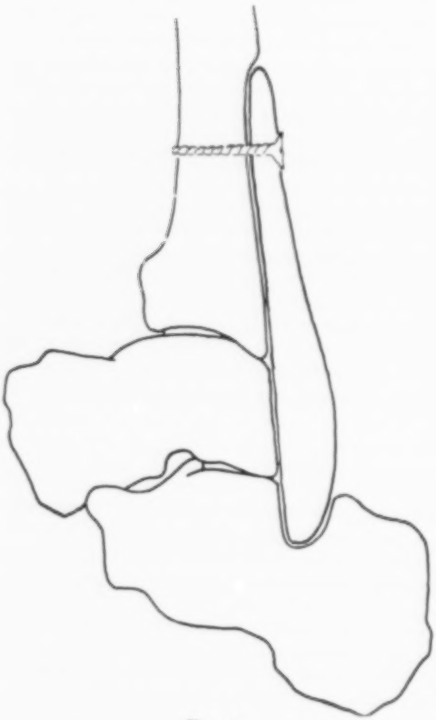


FIG. 1

Posterior arthrodesis of the ankle and the subtalar joints.

## SURGICAL TECHNIQUE

With the patient prone, an incision, approximately twelve centimeters long, is made posteriorly along the medial border of the tendo Achillis from the superior aspect of the calcaneus proximally. The Achilles tendon is sectioned by a Z-tenotomy in the frontal plane, the fascia of the flexor hallucis longus muscle is opened longitudinally, and the muscle is reflected medially in order to expose the posterior aspect of the tibiotalar and talocalcaneal joints. These joints are opened by transverse incisions and the cartilage is removed from the posterior portions of the joints. Removal of the cartilage from the anterior portions of the joints is not necessary, unless some major change in position is required. As shown in the illustration (Fig. 1), the tibia is osteotomized along the posterior aspect, including the posterior lip of the distal end of that bone, but care must be taken to avoid the medial malleolus. The osteotomy extends across the posterior aspect of the talus in the same plane, the foot being held in the pre-determined position. The osteotomy ends distally in an excavation one centimeter in depth in the superior aspect of the posterior portion of the calcaneus. The calcaneal excavation should be approximately one centimeter in the anteroposterior diameter, 2.5 centimeters in the transverse diameter. A graft of cortical and cancellous bone, 7.5 to 10 centimeters in length, 2.5 centimeters in width, and 1 centimeter thick, is taken from the posterior aspect of the ilium near the posterior superior spine. The graft is fitted to the osteotomized surface of the tibia, talus, and calcaneus, the cancellous side facing the osteotomized surface. After packing the joint spaces as necessary with cancellous chips, the graft is wedged into the hole in the calcaneus and fastened to the tibia by a Vitallium screw. The screw holds the graft in good contact with the osteotomy surface and provides fairly good stability of the fusion area, although forced dorsiflexion is to be avoided. After wound closure, a plaster cast is applied from toes to groin while the foot is held in the position desired for fusion—usually 5 degrees to 10 degrees of plantar flexion and in the neutral position or a few degrees of valgus in the coronary plane. The knee is held in approximately 30 degrees of flexion. This type of cast is used for two or three months

---

* Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Los Angeles, California, February 3, 1955.

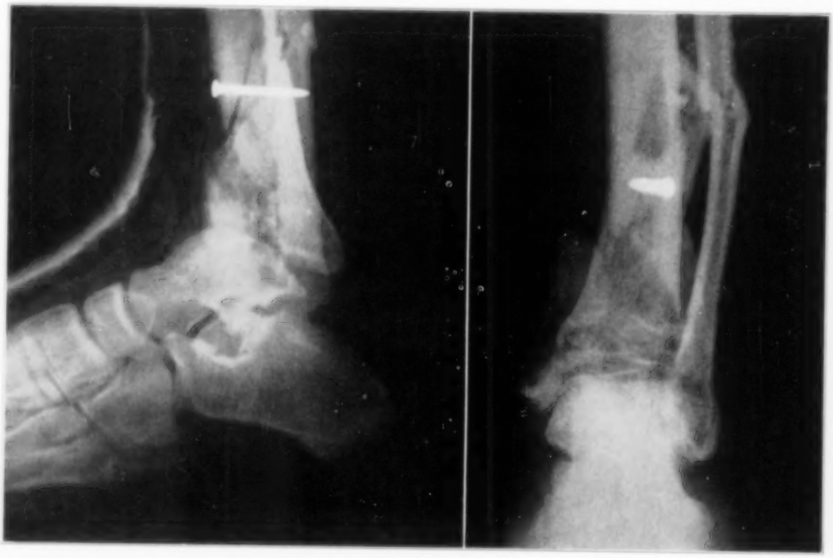


Fig. 2-A

Case 1. Comminuted fracture of the left ankle before arthrodesis.

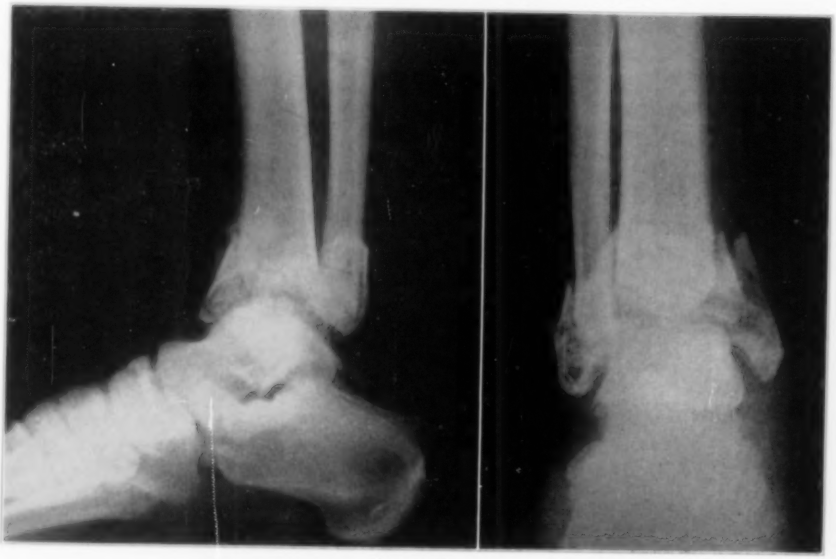


Fig. 2-B

Comminuted fracture of the right ankle before arthrodesis.

until roentgenograms reveal early union, at which time a short cast may be used until the healing is solid.

A posterior method of fusion is not suitable for general application or for all cases in which stabilization of these joints is required, but in certain situations it simplifies the approach to the problem of fusion. The advantages of posterior fusion include the following: (1) the simple surgical approach, (2) the long distal surface of the talus and calcaneus provided to receive a graft, (3) the ease with which the talocalcaneal joint may be included in the fusion area. However, when the talocalcaneal joint is normal, this method is ordinarily not applicable, as preservation of the motion of this joint is desirable from the functional standpoint, because it adds to the motion remaining in the tarsal region.

This method can be applied when the talocalcaneal and the tibiotalar joints are destroyed by injury.

Case 1. S. H., a man, twenty-eight years old, was first examined in October 1950, shortly after having been involved in a plane crash. In addition to other injuries,

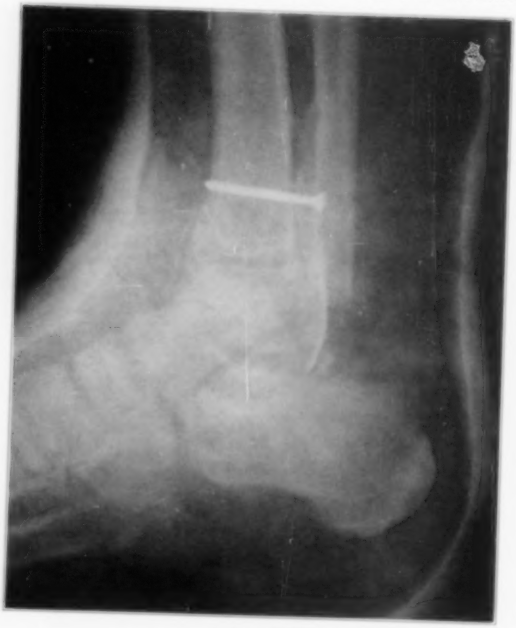


Fig. 2-C

Fig. 2-C: Roentgenogram of the right ankle seven weeks after posterior arthrodesis of the ankle and the subtalar joints.

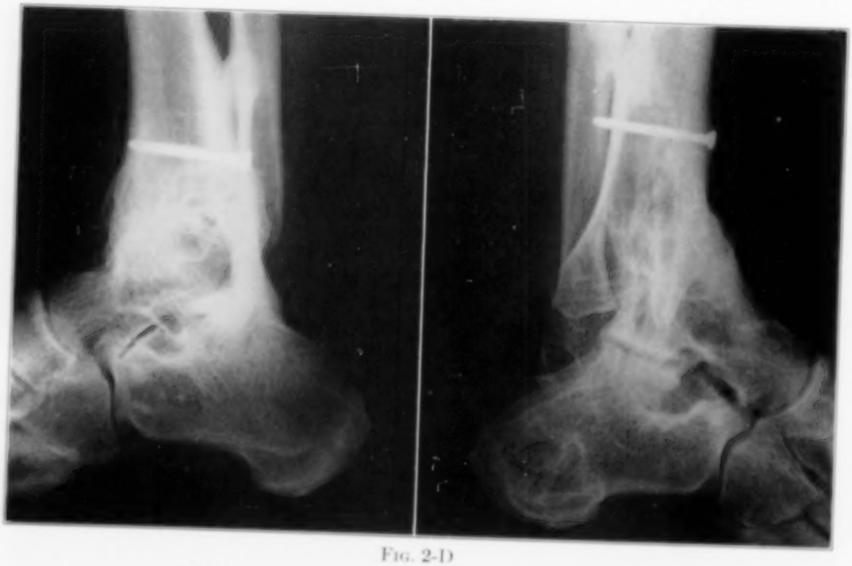


Fig. 2-D

Right Left

Roentgenograms made three and one half years after the posterior arthrodesis of the right ankle and subtalar joints and anterior arthrodesis of the left ankle joint.

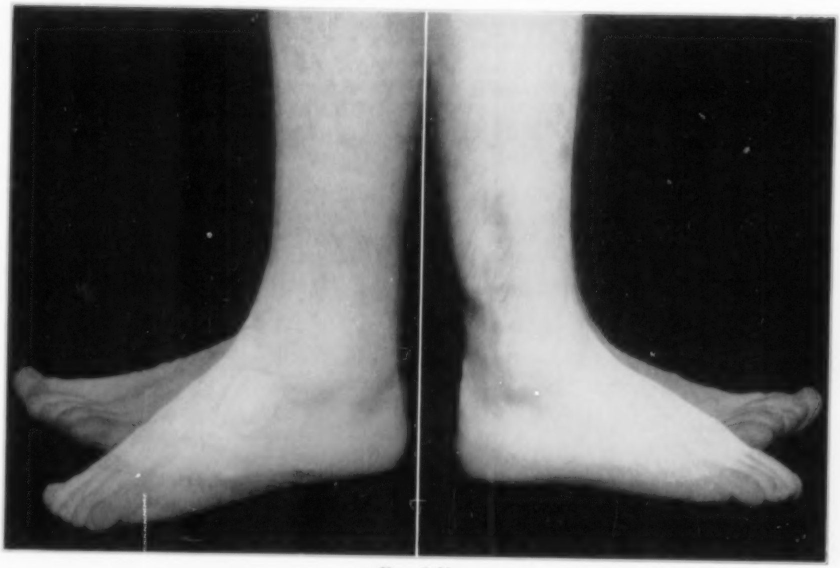


FIG. 2-E

Left Right

Photographs demonstrate the range of dorsal and plantar flexion remaining in the tarsal joints after arthrodeses of both ankle joints and of the right subtalar joint.

he had sustained compound comminuted fractures of both ankles. After supportive measures and initial surgery, it was obvious that arthrodesis of both ankles would be necessary (Figs. 2-A and 2-B). Approximately two months after operation, the arthrodeses were performed: on the left, an anterior approach was used and only the tibiotalar joint was fused; on the right, the posterior approach was used and both the tibiotalar and talocalcaneal joints were fused. The posterior method was chosen for the right ankle because there was evidence of damage to the posterior aspect of the talocalcaneal joint, in addition to rather massive scarring anteriorly (Fig. 2-C).

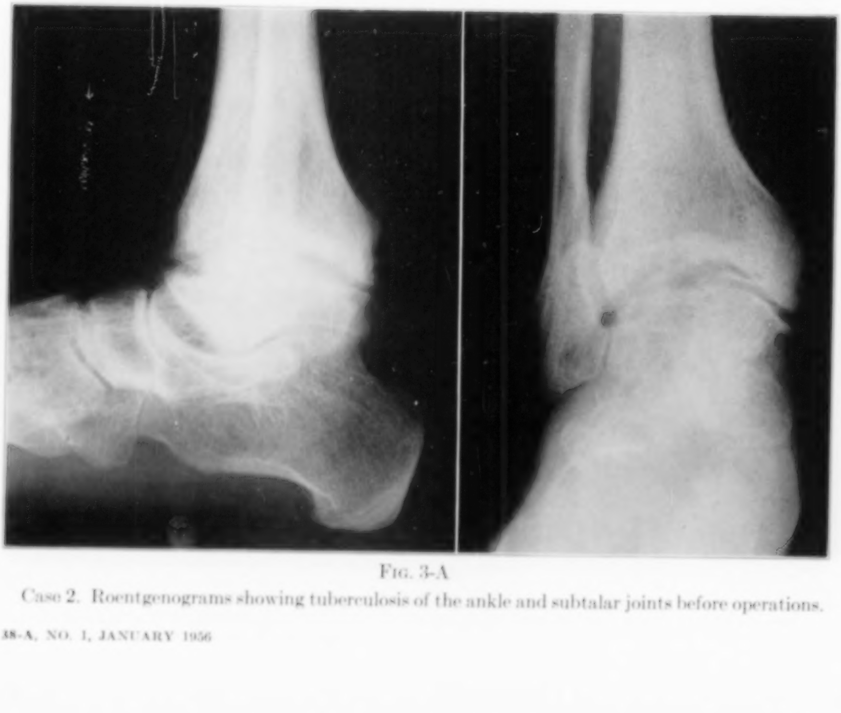


FIG. 3-A

Case 2. Roentgenograms showing tuberculosis of the ankle and subtalar joints before operations.

The results in this patient, three and one-half years after operation, provide an interesting comparison of function in the two types of arthrodesis. There was solid fusion in both ankles (Fig. 2-D). The range of motion remaining in the other joints of the foot differed, as was to be expected, on the two sides. At that time, the range of dorsal and plantar flexion (Fig. 2-E) amounted to 12 degrees in the right ankle, in which both the tibiotalar and talocalcaneal joints had been fused, and 20 degrees in the left ankle in which only a tibiotalar fusion had been performed. Motion involving inversion and eversion amounted to a total of 30 degrees on the right and 40 degrees on the left. The muscular strength of the two feet was equal and appeared to be within the normal range for the muscles involved.

At this time, three and one-half years after the fusion operation, there was no pain in either foot or ankle, although pain had persisted longer in the right foot and ankle during the recovery period. Actually, at the time of final examination, the patient had relatively little disability in either ankle or foot. He was employed as a construction foreman, was able to hunt, and had adjusted well to his diminished motion.

This method of posterior ankle arthrodesis was applied to two other males with injuries involving the tibiotalar and talocalcaneal joints. These patients, aged thirty and fifty-six years, respectively, had similar good results when examined at thirty-nine months and fourteen months, respectively, after operation.

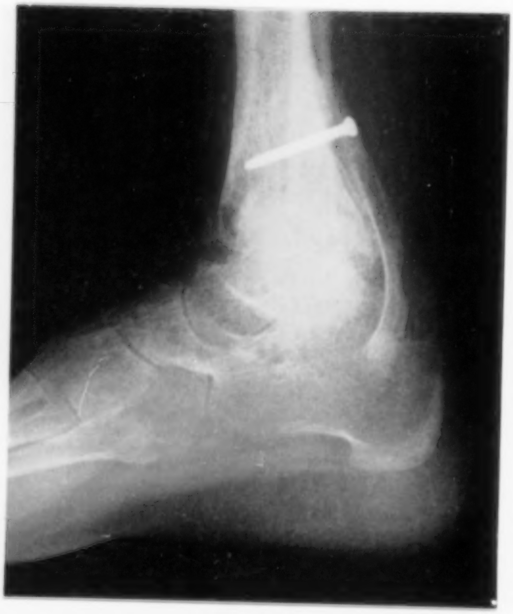


FIG. 3-B

Roentgenogram made two months after posterior arthrodesis of the ankle and the subtalar joints.

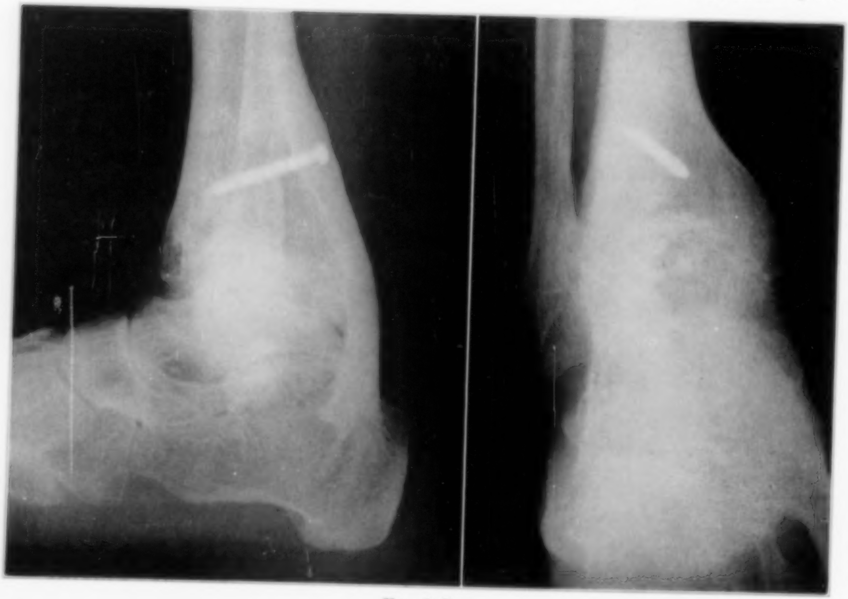


FIG. 3-C

Roentgenograms made four years after operation.

Tuberculosis of the ankle and talocalcaneal joints, as Campbell has already pointed out, can be treated by this type of arthrodesis, as shown in the following case report:

CASE 2. H. C., male, forty-three years old, was first examined seven years ago, and a positive diagnosis of tuberculosis of the ankle was made (Fig. 3-A). Arthrodesis was elected for definitive treatment. Following

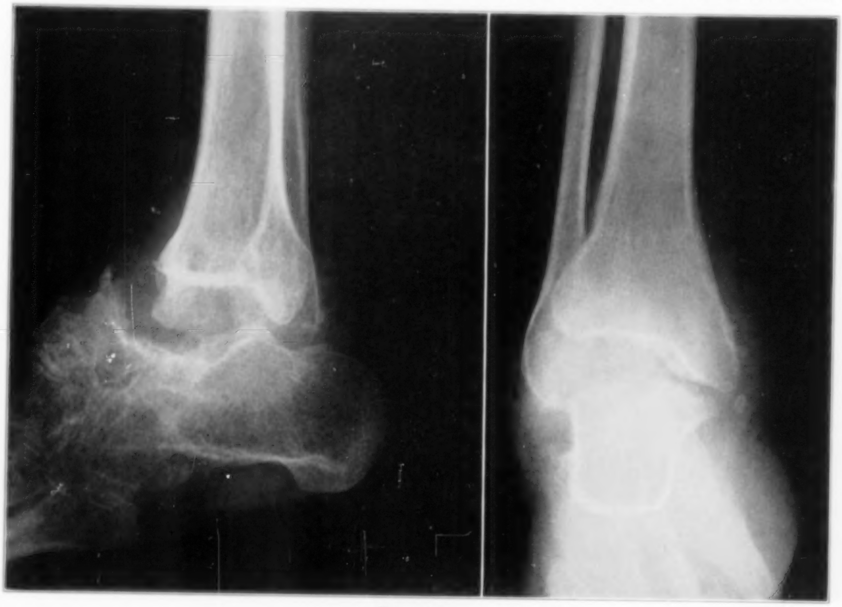


FIG. 4-A

Case 3. Roentgenograms showing the results of treatment for paralysis of the foot resulting from poliomyelitis by means of astragalectomy and fusion of the calcaneocuboid joint.

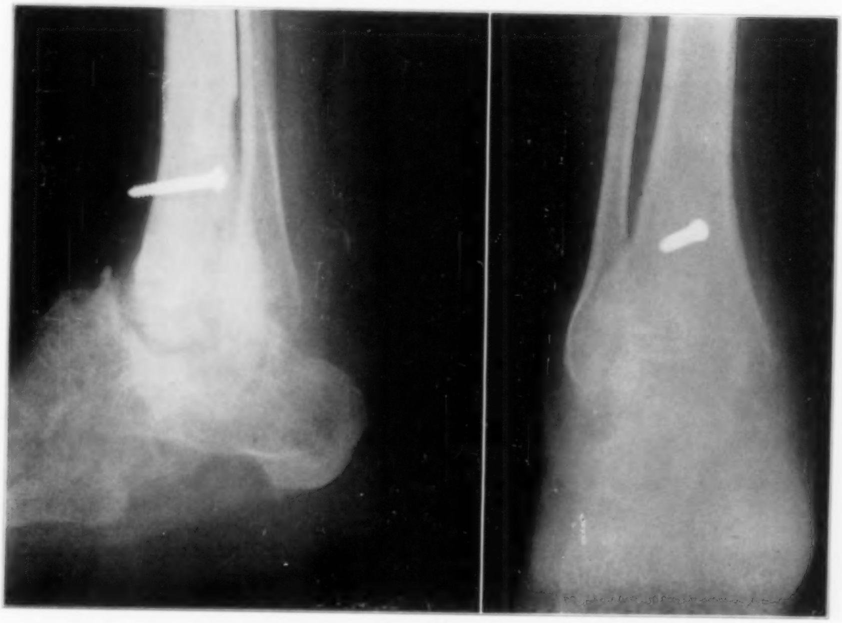


FIG. 4-B

Roentgenograms made two months after posterior arthrodesis of the tibia to the calcaneus.

a preliminary course of treatment with streptomycin, a posterior arthrodesis was carried out as described, except that the ankle and talocalcaneal joints were not opened and the graft was inserted with the cancellous surface directed posteriorly, resulting in its curve being convex posteriorly (Fig. 3-B). No attempt was made to change the position of the foot, which was in dorsiflexion of 5 to 10 degrees.

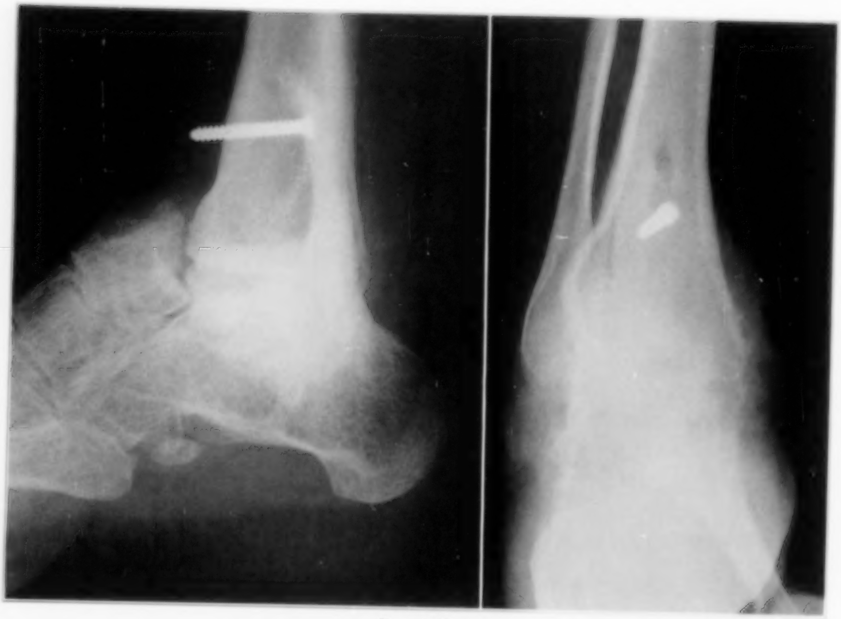


Fig. 4-C

Roentgenograms showing the result two years after the arthrodesis.

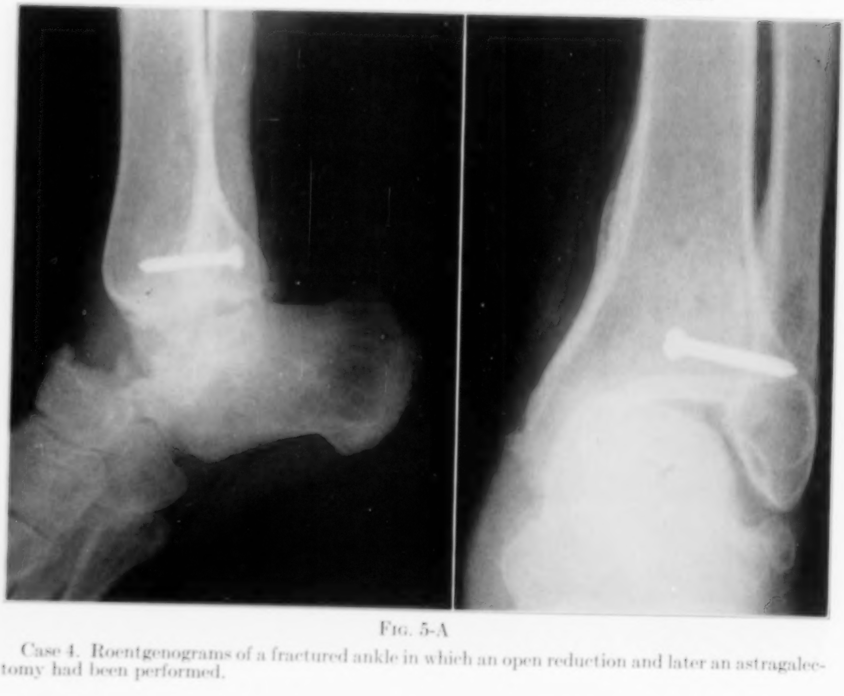


Fig. 5-A

Case 4. Roentgenograms of a fractured ankle in which an open reduction and later an astragalectomy had been performed.

After operation the patient did well, although on two occasions, each of short duration, there was drainage from an old sinus,—this was treated successfully by streptomycin.

The patient was last examined roentgenographically four years after operation (Fig. 3-C) and clinically six years postoperatively. He had had no symptoms referable to the ankle for four years and had done heavy work. He had a slight limp due to the dorsiflexion of his foot.

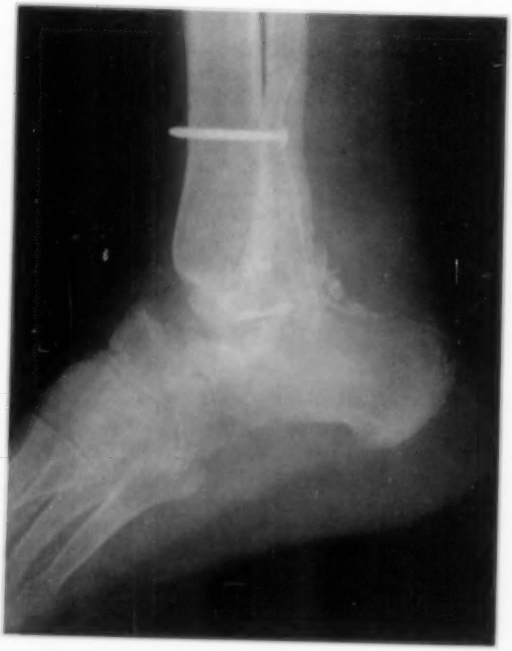


Fig. 5-B

Roentgenogram made two months after posterior arthrodesis of the tibia to the calcaneus.

In two instances we applied this method to patients who had had surgical astragalectomy with subsequent pain.

Case 3. E. B., a woman, forty-three years of age, had been treated a year before at another hospital by astragalectomy and fusion of the calcaneocuboid joint for a flail foot resulting from poliomyelitis. Severe ankle pain developed after operation and it could not be relieved by conservative therapy. Two months after she was first seen (Fig. 4-A), this patient was treated by a modification of the posterior method of ankle fusion (Fig. 4-B). The distal posterior portion of the tibia and the superior face of the calcaneus were osteotomized, exposing bleeding bone, and the defect was filled in part by cancellous and cortical blocks from the ilium. Over this was placed the posterior graft, as described. Because of the previous fusion of the calcaneocuboid joint and in the absence of deformity and instability of the foot, further arthrodeses were not performed in the foot.

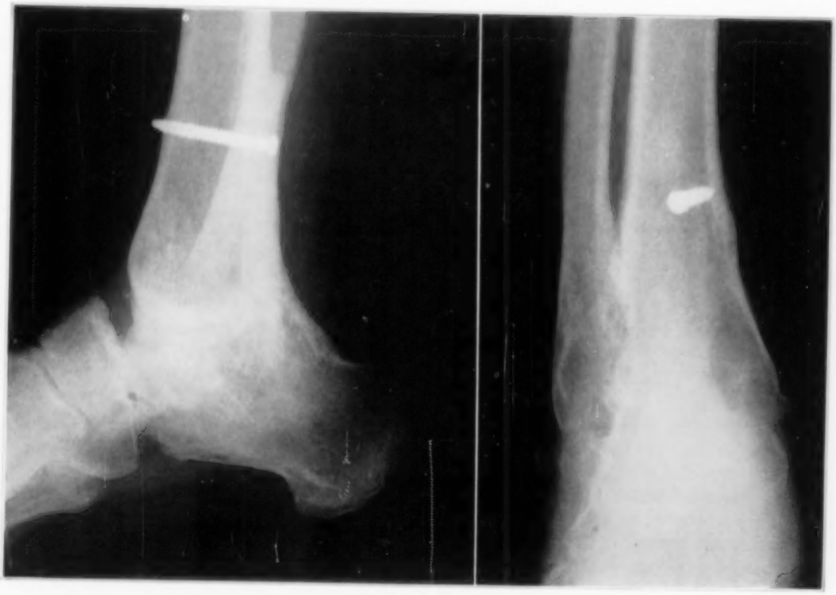


Fig. 5-C

Roentgenograms made two and one-half years after arthrodesis of the ankle.

The final examination was made twenty-eight months postoperatively (Fig. 4-C). The patient had had no pain for fourteen months, had flail motion from the neutral position to 10 degrees of plantar flexion without pain, and although handicapped by partial paralysis of the lower extremities, as well as by diminished ankle function, she was able to work as a general duty nurse in a small hospital in northern New Hampshire.

CASE 4. L. D., a woman of forty-one years of age, had also been treated by astragalectomy at another hospital, approximately three years before, because of the complication of surgical sepsis in a comminuted fracture of the ankle which had initially been treated by open reduction (Fig. 5-A).

Because there was disabling pain on weight-bearing, an arthrodesis similar to that performed on the patient in Case 3 was performed (Fig. 5-B).

The patient was last examined two and one-half years after operation and at that time solid union was found (Fig. 5 C). The patient described pain referable to the longitudinal arch of the foot and to the lateral aspect of the mid-tarsal region on excessive use of the foot. This pain was not severe or disabling and had been decreasing slowly and steadily. It was interesting to note that, in contrast with similar patients who had, after operation, good strength in the muscles controlling the foot and no pain, this patient had moderately diminished strength in these muscles, as shown by manual testing. Although in this instance the impaired strength of the muscles may not have been the sole cause of pain, it could explain the long persistence of symptoms in this patient. In our experience, the restoration of strength of the leg muscles, except in the flail foot, by an exercise program is a very important part of the postoperative care of these patients.

In conclusion, the decision to use the posterior method of ankle fusion depends largely on whether it is desirable or permissable to obliterate function in the talocalcaneal joint, as well as in the ankle joint. When such is the case, arthrodesis by the posterior method offers a reasonably simple solution for certain complicated and unusual problems in which ankle arthrodesis is indicated.

## REFERENCES

1. BARR, J. S., and RECORD, E. E.: Arthrodesis of the Ankle Joint, Indications, Operative Technic and Clinical Experience. New England J. Med., **248:** 53–56, 1953.
2. BRITTAIN, H. A.: Architectural Principles in Arthrodesis, pp. 58–63. Baltimore, The Williams and Wilkins Company, 1942.
3. CAMPBELL'S OPERATIVE ORTHOPAEDICS. Ed. 2, pp. 533, 1345. Edited by J. S. Speed and Hugh Smith. St. Louis, The C. V. Mosby Co., 1949.
4. CARMACK, J. C., and HALLOCK, HALFORD: Tibiotarsal Arthrodesis after Astragalectomy. A Report of Eight Cases. J. Bone and Joint Surg., **29:** 476–482, Apr. 1947.
5. GALLIE, W. E.: Subastragalar Arthrodesis in Fractures of the Os Calcis. J. Bone and Joint Surg., **25:** 731–736, Oct. 1943.
6. GLISSAN, D. J.: The Indications for Inducing Fusion at the Ankle Joint by Operation, with Description of Two Successful Techniques. Australian and New Zealand J. Surg., **19:** 64–71, 1949.
7. HALLOCK, HALFORD: Arthrodesis of the Ankle Joint for Old Painful Fractures. J. Bone and Joint Surg., **27:** 49–58, Jan. 1945.
8. MEAD, N. C.: Arthrodesis of the Ankle Joint. A Simple, Efficient Method. Quarterly Northwestern Univ. Med. School, **25:** 248, 1951.

## DISCUSSION

DR. LEWIS CLARK WAGNER, NEW YORK, N. Y.: Of all the approaches to the ankle joint and talocalcaneal joint, only two are valuable. Each possesses simplicity. They are the anterior approach and the posterior approach.

1. The *anterior approach* for arthrodesis is probably the best for patients in whom a pan-arthrodesis is indicated because of the need for correction of deformities. It should be done in two stages as follows: (a) a *triple* arthrodesis with *correction* of the deformity of the foot is done; (b) three weeks later, the ankle arthrodesis with sliding bone graft from the tibia is performed. Metallic fixation is not needed and plaster-of-Paris fixation is used in the desired position. These two operations usually give the result desired.

2. *Posterior arthrodesis* is indicated in patients needing correction of old deformities of the calcaneus following astragalectomy, as Dr. Staples has indicated. In tuberculous or infected joints of long-standing which are quiescent, the risk of the procedure will be less when this approach is used. I disagree that the use of a bone transplant from another part of the body is necessary, as sufficient bone for the operation can be secured from the site of operation, — that is, from the tibia. I dislike using any metallic fixation, as I think it is not particularly needed. A well fitting plaster-of-Paris dressing is all that will be required, and it is

*(Continued on page 83)*

# THE MECHANISM OF ANKLE INJURIES

BY BARNARD KLEIGER, M.D., NEW YORK, N. Y.

*From The Hospital for Joint Diseases and The Leo Mayer Orthopaedic Group, New York*

Even before the advent of roentgenography, much had been learned about the mechanism of injury to the ankle on the basis of clinical examinations, post-mortem dissections, and the laboratory production of experimental injuries in cadavera. The best known works prior to roentgenography were those of Hönigschmied and Maisonneuve. In 1922, the literature was reviewed by Ashhurst and Bromer and, more recently, by Bonnin and Lauge [9]. Much has been written on this subject since the introduction of roentgenography, but the works of Ashhurst and Bromer, Ragnar Magnusson [16-18], Watson-Jones, Lauge-Hansen [9-11], and Bonnin deserve special mention.

Earlier authors and many recent authors have adequately described the fractures resulting from ankle injury and some have even described the ligamentous tears. However, the ankle instability that results from injury to the ligaments has been largely neglected until recent years. The recognition of inversion instability, or tilting of the talus when the foot is inverted, was made general by Watson-Jones and others [2,4,6,14]. Lateral ankle instability or lateral movement of the talus has been described [2,8,10], but it has not received its proper emphasis and has been greatly neglected in clinical practice. This report will describe the more common types of instability, the mechanism which produced them, and the author's technique of demonstrating this instability roentgenographically. The anatomical structures contributing to the maintenance of ankle

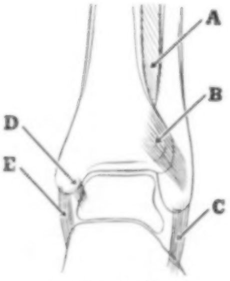


FIG. 1-A

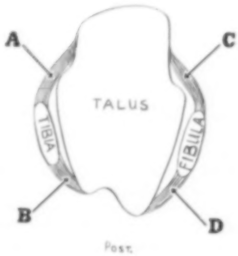


FIG. 1-B

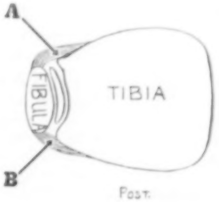


FIG. 1-C

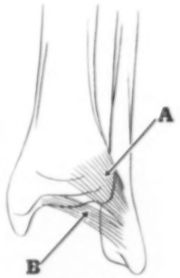


FIG. 1-D

Fig. 1-A: Diagram of the anterior aspect of the ankle: The talus fits the mortise accurately and its articular surface closely parallels the articular surface of the tibia. Normally, with the foot at 90 degrees, no lateral mobility of the talus exists. The fibular malleolus is longer than the tibial malleolus. The ligaments are: (*A*) the interosseous membrane which becomes thickened at the distal end of the leg to form the interosseous ligament, (*B*) the anterior inferior tibiofibular ligament, (*C*) the calcaneofibular ligament, (*D*) the deep fibers of the middle portion of the deltoid ligament, and (*E*) the calcaneotibial fibers of the deltoid ligament.

Fig. 1-B: Diagram of a section through the transverse plane of the talus and malleoli. The superior articulating portion of the talus is wedge-shaped, the greater width being anterior, so that the tibial and fibular malleoli prevent posterior displacement as well as medial and lateral mobility. The ligaments are (*A*) the anterior talotibial fibers of the deltoid ligament, (*B*) the posterior talotibial fibers of the deltoid ligament, (*C*) the anterior talofibular ligament, and (*D*) the posterior talofibular ligament.

Fig. 1-C: Sectional diagram through the tibiofibular syndesmosis proximal to the ankle joint. The fibula fits in a groove on the lateral aspect of the tibia and there is an upward prolongation of synovial membrane of the ankle between the tibia and fibula. The tibial groove is bounded anteriorly by a tubercle and posteriorly by a tubercle. The fibula is held firmly in this groove by the following ligaments: (*A*) the anterior inferior tibiofibular ligament which connects the distal end of the fibula with the anterior tubercle of the tibia; and (*B*) the posterior inferior tibiofibular ligament which connects the distal end of the fibula to the posterior tubercle of the tibia. The interosseous ligament and membrane pass between the shafts of the tibia and the fibula (see Fig. 1-A).

Fig. 1-D: Drawing of the posterior view of the tibiofibular syndesmosis, showing (*A*) the posterior inferior tibiofibular ligament and (*B*) the inferior transverse ligament.

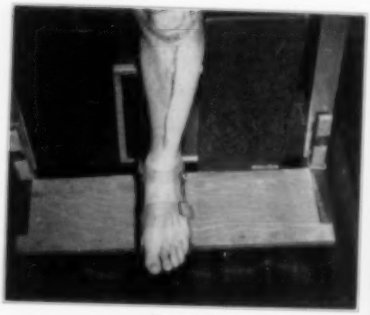


FIG. 2-A

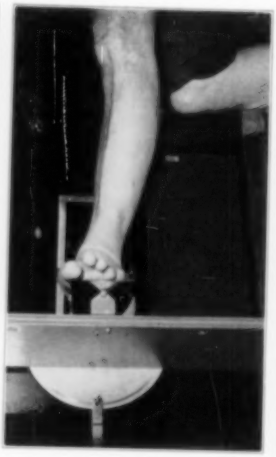


FIG. 2-B

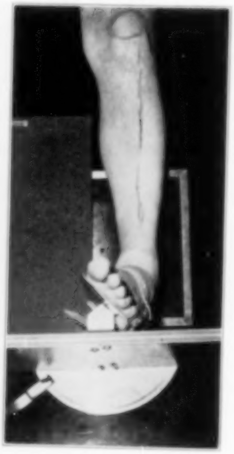


FIG. 2-C

Technique of making stress roentgenograms of the foot in lateral rotation.

Fig. 2-A: A foot-holder is used in making stress roentgenograms of the ankle. It consists of a plastic foot piece on a metal pivot, controlled by a handle behind the base board. The foot is strapped in the holder with the cassette placed beneath the ankle. The sole of the foot is flat against the foot-holder and the patella points directly upward.

Fig. 2-B: With the foot held in the foot piece, the patient turns onto the uninjured side, holding the uninjured leg behind him. In this way, the injured leg is rotated medially and the foot is in a position of relative lateral rotation.

Fig. 2-C: The heel is held in inversion by angulating the foot-holder, the foot being held at 90 degrees with relation to the long axis of the leg.

Fig. 3: Injuries caused by lateral rotation of the foot or medial rotation of the leg when the foot is fixed. When the foot is forced into lateral rotation, (*A*) the anterior talotibial fibers of the deltoid may be ruptured. Then the talus strikes the anterior aspect of the distal end of the fibula. (*B*) The posterior talofibular ligament pulls on the distal end of the fibula. This places tension on the anterior inferior, posterior inferior, and the inferior transverse tibiofibular ligaments in sequence. (*C*) When these ligaments have given way and the talus moves laterally, tension is placed on the interosseous ligament and membrane. When these tear, the tibiofibular syndesmosis is disrupted.

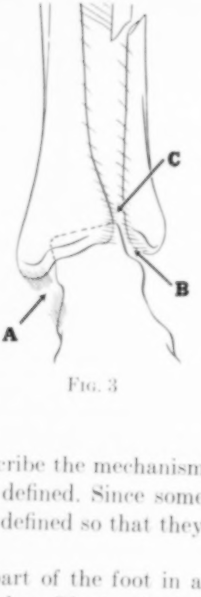


FIG. 3

stability may be summarized by a series of diagrams (Figs. 1-A through 1-D).

### DEFINITIONS OF ANKLE MOTION

In previous reports, motions of the ankle have been used to describe the mechanism of ankle injuries but in terms which have not always been clearly defined. Since some differences in terminology exist, the terms used in this report will be defined so that they may be correlated with those used by other authors [1,2,5,9,11,15–21,24].

*Dorsiflexion* at the ankle is defined as the motion of the fore part of the foot in a cephalad direction on a transverse axis through the body of the talus. *Plantar flexion* is defined as the opposite motion through the same axis. These movements take place in part in the tibiotalar joint.

*Lateral rotation* at the ankle joint is defined as lateral deviation of the fore part of the foot on a longitudinal axis through the tibia. *Medial rotation* involves a medial deviation of the fore part of the foot through the same axis. These motions take place in part in the tibiotalar joint. When the ligaments are intact and the foot is in the neutral position this range of movement is very slight; if the foot is in plantar flexion the range of rotation is slightly increased. Should certain ligaments be torn, the range of rotation may be increased, but when the range of rotation has increased more than a slight degree, it is considered to be pathological and indicative of ligament injury.

*Eversion* of the foot is accompanied by lateral rotation and displacement of the heel on a longitudinal axis through the calcaneus; *inversion* by medial rotation and displacement of the heel on a longitudinal axis. These motions normally take place largely in the subtalar and mid-tarsal joints, but when certain ligaments are torn or lengthened may take place in the tibiotalar joint. The terms *abduction* and *adduction* have been used by others as synonyms for eversion and inversion of the ankle joint. They are more appropriately applied to the lateral and medial deviation of the fore part of the foot on a dorso-plantar axis through the mid-tarsal joints. The terms *pronation* and *supination* have also been used, but these are compound motions of the foot. Pronation is a combination of eversion of the foot, lateral rotation at the ankle, and abduction of the fore part of the foot. Supination is a combination of inversion of the foot, medial rotation at the ankle, and adduction of the fore part of the foot.

### ROENTGENOGRAPHIC TECHNIQUE

This study has confirmed the observations of Lauge-Hansen [10] that simple anteroposterior, lateral, and oblique roentgenograms are not adequate to study an ankle injury. These views will demonstrate bone injury but may not show ligament injury. Adequate roentgenographic study requires that a view be made while stress is applied to the foot in lateral rotation and another in inversion to demonstrate ligament injury.

It is necessary, therefore, to take at least four views. First, the patient's foot is strapped in a plastic foot-holder (Fig. 2-A) and an anteroposterior roentgenogram is made. With the foot held strapped in the vertical position, the patient then lies on the uninjured side. In this way, the leg is rotated medialward in relation to the foot, the foot remaining fixed and laterally rotated in relation to the leg, and another roentgenogram is made without changing the position of the x-ray tube (Fig. 2-B). The foot-holder is then turned to a position of inversion, and another anteroposterior view is made (Fig. 2-C). Finally, a true lateral view is made.

By comparing the roentgenograms made in the neutral position without stress with those made with the foot in varying positions under stress, instability can be demonstrated. Stress placed on the foot in lateral rotation produces lateral ankle instability, with or without diastasis and eversion instability. Inversion stress demonstrates inversion instability. With this technique even minor degrees of instability can be determined by measuring the width of the joint space at the site of instability and by comparing it with the width of the rest of the joint space. Ordinarily the patient does not need anaesthesia for the stress roentgenograms, if the manoeuvres are performed slowly and if the patient is encouraged to carry out most of them himself. When the stress roentgenograms are made without anaesthesia even slight instability is significant, because the range of abnormal mobility is less than when anaesthesia is used. When swelling or muscle spasm prevents the application of stress, local or general anaesthesia may be used. All of the stress roentgenograms reproduced in this report were made without anaesthesia. Oblique views are made only when the previous views show pathological changes in the bone that would be more clearly demonstrated by an oblique projection.

### DETERMINATION OF THE MECHANISM OF INJURY

In each case the patient was questioned regarding the position of the foot at the time of injury, the character of the ground and the direction of the slope at the site of injury, and the intensity and character of the injuring force. Despite careful interrogation, only limited information was obtained, because the accidents happened so quickly that the patients had little opportunity to make careful observations and subsequently they were in too much pain to keep this information in mind. However, some characteristic answers were noted. Patients with oblique fractures of the distal end of the fibula often recalled a twist, although they could not always describe accurately the direction of the twist. Those with inversion injuries often remembered that the foot had turned "inward" under the leg. Those with eversion and complex mixed fractures could rarely describe the injury except to say that they had struck the ground hard.

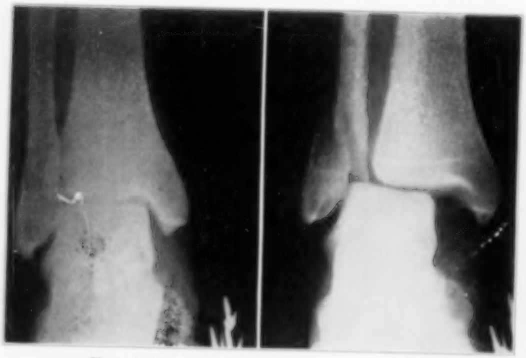


FIG. 4-A FIG. 4-B

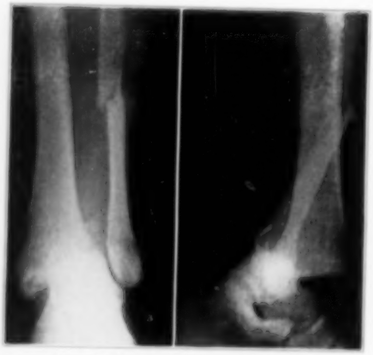


FIG. 5-A FIG. 5-B

Figs. 4-A and 4-B: Roentgenograms of an ankle showing a characteristic oblique fracture of the distal end of the fibula with lateral ankle instability, but without tibiofibular diastasis.

Fig. 4-A: The mortise appears to be normal.

Fig. 4-B: The same ankle under lateral rotation stress shows relatively slight lateral movement of the distal fibular fragment but marked displacement of the talus.

Figs. 5-A and 5-B: Posterolateral dislocation of the talus with tibiofibular diastasis caused by lateral rotation.

Fig. 5-A: The talus is displaced posterolaterally and the tibiofibular syndesmosis is greatly widened.

Fig. 5-B: Showing the posterior displacement of the talus.

The mechanism of the injury was more accurately determined by a study of the roentgenograms showing the fracture lines and the direction of the displacement. The characteristics of ankle injuries have been previously described [1,2,5,9,11,16–19,22] and, with few exceptions, they paralleled our own interpretations. The information obtained by the roentgenographic approach was considered more reliable than that gained from interrogation and was given precedence when the roentgenographic deductions conflicted with the patient's description of the injury.

Most reports have emphasized fractures of the ankle. However, ligament injury is of great importance. Regardless of the mechanism involved in the injury, the various degrees of ligament damage may be defined as follows: *Sprains* are gross ruptures of the ligaments without joint instability. *Joint instability* occurs when there is rupture of enough ligaments to permit abnormal increase in the motion of the talus in the ankle-joint mortise. *Dislocation* occurs when the ligaments are so completely torn that the talus is displaced from the mortise.

Ligament injuries may occur with or without fracture; Leitner and Wilson and his colleagues have reported complete talar dislocation without any fracture about the ankle.

## TYPES OF INJURY

Injuries of the ankle are most frequently caused by forces in a lateral direction, namely, lateral rotation and eversion.

### *Lateral Rotation Injuries*

Lateral rotation of the foot, or medial rotation of the leg when the foot is fixed (Fig. 3), is the most frequent cause of ankle injury [1,2,3,9,11,16]. Normally, the talus is held firmly by the malleoli and the ligaments, and it cannot rotate either medially or laterally when the foot is held at 90 degrees; but, with sufficient force, the talus rotates laterally to tear the medial portion of the capsule and the anterior talotibial fibers of the deltoid ligament. The lateral surface of the talus then strikes the anterior aspect of the fibular malleolus while simultaneously the fibular malleolus is pulled posteriorly by the posterior talofibular ligament. This manoeuvre tears the anterior and posterior inferior

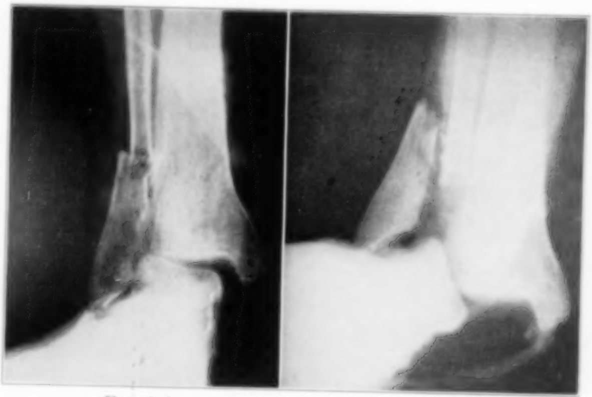


FIG. 6-A FIG. 6-B

Experimental roentgenograms of a cadaver.

Fig. 6-A: Lateral ankle instability without diastasis. The fibula has been osteotomized. The deltoid, anterior and posterior inferior tibiofibular ligaments have been cut, but the inferior transverse ligament is intact.

Fig. 6-B: Lateral ankle instability with diastasis of the tibiofibular syndesmosis. The inferior transverse ligament has also been cut. The fibula has left the tibial groove and the talus has dislocated laterally.

tibiofibular ligaments and the inferior transverse ligament, the interosseous ligament, and the interosseous membrane in sequence. One or all of these ligaments may be torn whether or not fracture occurs. When the appropriate ligaments are torn the talus loses part of its attachment to the medial malleolus and the distal end of the fibula is released from the tibia. Lateral rotation of the foot then results in lateral displacement of the talus and the ankle becomes unstable laterally (Figs. 4-A and 4-B). When all the ligaments holding the distal fibula to the tibia are torn then the tibiofibular syndesmosis is disrupted and diastasis appears (Figs. 5-A through 6-B).

It is important to distinguish between lateral ankle instability with and that without tibiofibular diastasis. *Diastasis* refers specifically to lateral displacement of the fibula from the tibial groove. *Lateral ankle instability* indicates excessive lateral displacement of the talus with widening of the mortise and of the space between the talus and the tibial malleolus. This instability may exist without diastasis, if the fibula is fractured below the level of the interosseous or tibiofibular ligaments. The fibular shaft is then held in the tibial groove, but the small distal fibular fragment rotates laterally and posteriorly with the talus. It is also possible for lateral ankle instability to exist without diastasis and without a fibular fracture. If the anterior inferior tibiofibular ligament and the interosseous ligament are torn and the posterior inferior tibiofibular ligament remains intact, the fibula may rotate in the tibial groove without completely leaving it. The talus may then rotate laterally with the fibula and pass around the anterior aspect of the tibia.

The most characteristic fracture due to lateral rotation of the foot is an oblique fracture of the fibula, the proximal end of the line of fracture being located posteriorly and the distal end being located anteriorly at the level of the ankle joint. When seen in roentgenograms made in the anteroposterior view, the position of the fragments is usually so good that it is often difficult to see the fracture line (Fig. 4-A). If the tibiofibular syndesmosis is disrupted before the fibula is fractured, a fracture of the shaft may be produced at a higher level (Fig. 5-A). The fracture of the fibula occurs at the level of the most proximal portion of the ligamentous tear.

When force is applied, the ligaments are not always ruptured but may as often be avulsed from the bony attachment at either end. Thus, the anterior inferior tibiofibular ligament may avulse the tubercle on the anterolateral border of the tibia [2,16] (Figs. 7-A and 7-B) or, rarely, the anterior aspect of the fibula [2,9,11,12].

There are several mechanisms of the so-called chip fracture of the posterior lip of the tibia (Fig. 8) although lateral rotation is the most common. The tubercle on the posterolateral border of the tibia and the posterior articular margin are contiguous structures, and it is usually impossible to determine by the roentgenographic techniques now available which of these structures is the one actually involved. Because of this, all of the chip fractures of the posterior lip of the tibia are classified together. A lateral rotation

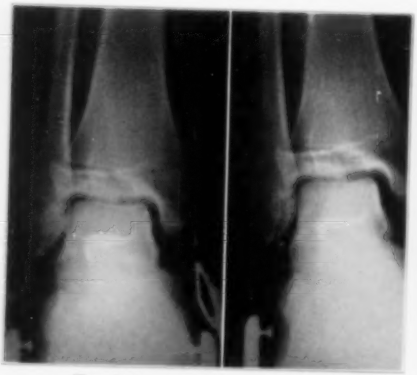


Fig. 7-A Fig. 7-B

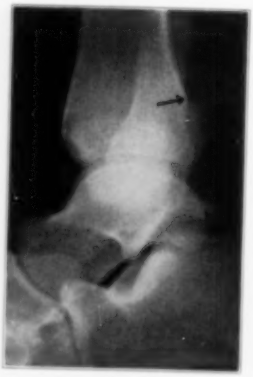


Fig. 8

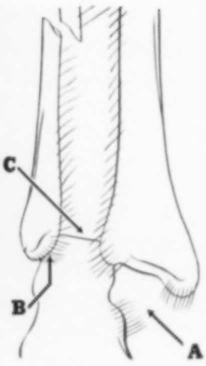


Fig. 9

Figs. 7-A and 7-B: Fracture of the tubercle on the anterolateral aspect of the tibia, the avulsed fragment being composed of most of the lateral portion of the tibial epiphysis.

Fig. 7-A: In the neutral position, the mortise appears to be normal and the fragment is in satisfactory position.

Fig. 7-B: When lateral rotation stress is applied, the fragment can be seen to move laterally and the mortise widens.

Fig. 8: Chip fracture of the posterior lip of the tibia. The fracture line extends vertically along the posterior articular margin without actually involving the articular surface.

Fig. 9: Drawing showing injuries caused by eversion of the foot. (*A*) Tension is placed on the deltoid ligament of the ankle, tearing it or causing the medial malleolus to be fractured. (*B*) The talus then strikes the medial aspect of the fibular malleolus. If the tibiofibular ligaments do not tear, the lateral articular surface of the talus or the distal end of the fibula is fractured. If the tibiofibular ligaments tear, but the interosseous ligament does not, the fibula is fractured obliquely at the level of the ankle joint, and lateral instability of the talus may result. (*C*) If the interosseous ligament and membrane tear, the fibular shaft is fractured and is displaced laterally to cause diastasis.

or eversion force may exert pressure against the fibula which causes the posterior inferior tibiofibular ligament to be avulsed with its bony attachment to the tubercle on the posterior portion of the tibia, or it may cause the inferior transverse ligament to be avulsed with its bony attachment to the posterior articular margin of the tibia. The tubercle on the posterior aspect of the tibia may also be fractured by the direct impact of the posterior aspect of the fibula as lateral rotation forces it laterally and posteriorly. Fractures of the posterior articular margin of the tibia as a result of compression by the talus when it is forced upward and backward may also occur and these will be discussed under compression injuries.

### *Eversion Injuries*

Eversion of the foot is not as often the cause of injury to the ankle as lateral rotation [1,2,3,9,11,16,17,18], but the sequelae are just as serious. When the heel is everted tension is put on the deltoid ligament and it may tear or pull off the tibial malleolus. The lateral articular surface of the talus then strikes the medial face of the fibular malleolus, tearing the tibiofibular ligaments simultaneously and then the interosseous ligament and membrane (Fig. 9). Thus the ligament injuries due to eversion may produce eversion instability (Fig. 10), or lateral ankle instability without diastasis (Fig. 11) or with diastasis (Figs. 12-A and 12-B) of the tibiofibular syndesmosis.

The characteristic fracture of the tibia resulting from eversion is a transverse or slightly oblique fracture of the medial malleolus, the fracture line ending laterally at, or slightly below, the mortise angle (Figs. 13-A, 13-B, and 15). When the foot is in eversion, the powerful central portion of the deltoid ligament pulls the malleolus laterally away from its base. The malleolar fragment of the tibia may be displaced anteriorly by the tendon of the tibialis posterior or it may be pulled forward as the foot falls into the equinus position after the injury.

As the talus becomes increasingly everted, the pressure of its lateral articular surface

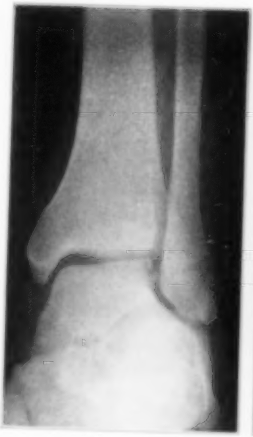


FIG. 10

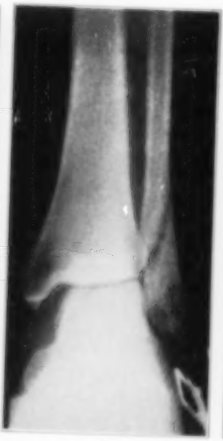


FIG. 11

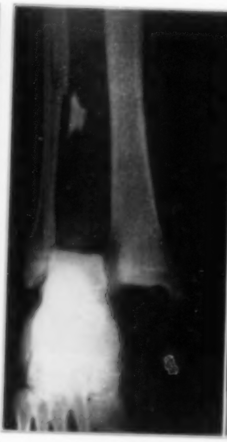


FIG. 12-A

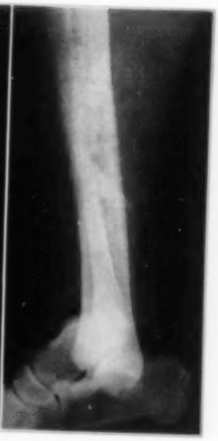


FIG. 12-B

Fig. 10: Eversion instability due to a tear of the deltoid ligament. Note also the chip fractures of the superior and lateral articular surfaces of the talus at the site of impact against the tibia and fibula.

Fig. 11: Lateral ankle instability without diastasis and an oblique fracture of the fibula due to eversion.

Figs. 12-A and 12-B: Fracture of the fibular shaft with lateral dislocation of the talus and diastasis as a result of eversion.

Fig. 12-A: Anteroposterior roentgenogram shows that the fibula is displaced laterally and that the talus is dislocated between it and the tibia.

Fig. 12-B: The lateral view shows no posterior displacement.

against the fibular malleolus increases. If the tibiofibular ligaments do not tear, the distal end of the fibula is comminuted and angulated laterally (Fig. 13-A). If, however, the tibiofibular ligaments rupture, the fibula is fractured obliquely at the level of the ankle joint. The plane of the fracture line is at a right angle to that of the fracture caused by lateral rotation, the proximal end of the fracture line being located posterolaterally, and its distal end anteromedially. The obliqueness is best seen in the anteroposterior roentgenogram, for in that projection the angulation or lateral displacement of the distal tibial fragment is clearest (Fig. 14). If the interosseous ligament and membrane also tear, the fibular shaft may be fractured proximal to the tear (Fig. 12-A); the fracture may be transverse, comminuted, or oblique. The fibula may be fractured at two levels, although this is infrequent.

Fractures of the fibular shaft with lateral ankle instability but without diastasis are always due to lateral rotation. When diastasis, as well as lateral ankle instability, is present with a fracture of the fibular shaft, the ligaments injured are the same, whether the injury has been a result of a lateral-rotation or eversion force. However, in lateral-rotation injuries, the ligaments are torn in sequence, and they are torn simultaneously in eversion injuries. Therefore, it may be difficult to tell which mechanism caused the injury unless additional factors, such as talar displacement and associated fractures, provide the information.

As the talus becomes increasingly everted, its superolateral margin may strike the lateral margin of the distal articular surface of the tibia and push it upward with the anterior fragment of the tubercle of the tibia (Fig. 14). At times the articular surface of the talus in the region of the impact is injured (Fig. 10), or the lateral articular surface of the talus may be fractured when it strikes the distal end of the fibula (Fig. 15).

It is remarkable how trauma may cause injury to one ligament without injuring an adjacent ligament. Thus, in one case, the force tore the superficial calcaneotibial fibers of the deltoid ligament, whereas the deep fibers of the middle portion of the deltoid ligament were spared. The torn ligament permitted the heel to become markedly everted during standing, but the talus remained within the mortise (Figs. 16-A and 16-B).

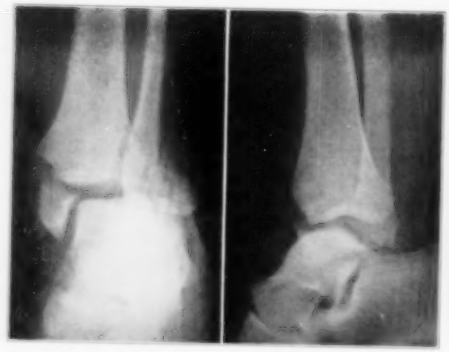


FIG. 13-A FIG. 13-B

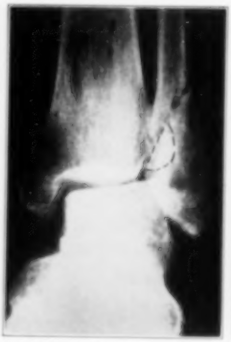


FIG. 14

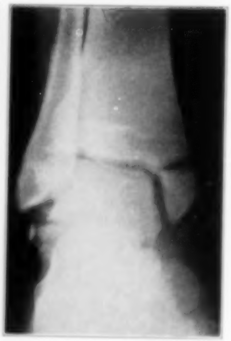


FIG. 15

Eversion fracture of the tibial and fibular malleoli.

Fig. 13-A: Anteroposterior roentgenogram. The medial malleolus is fractured obliquely at its base and is displaced laterally. The fibular malleolus is fractured below the attachment of the tibiofibular ligaments and is comminuted and angulated laterally. There is no disturbance of the tibiofibular syndesmosis.

Fig. 13-B: The lateral view. The tibial malleolus, talus, and foot are displaced anteriorly.

Fig. 14: Eversion fracture of the fibula and anterior tibial tubercle. The fibular fracture line is oblique, beginning superolaterally and ending inferomedially and the plane of the fracture line is at a right angle to that of the lateral rotation fracture. The lateral margin of the distal articular surface of the tibia is also fractured and the anterior portion of the tubercle of the tibia is elevated (fragment outlined in ink).

Fig. 15: Eversion fractures of the tibial malleolus and of the lateral articular surface of the talus. The tibial malleolus is displaced distally to the level of the distal end of the fibula.

### *Inversion Injuries*

Inversion of the heel often causes injury to the anterior talofibular ligament, the posterior talofibular ligament, and the calcaneofibular ligament of the ankle (Fig. 17). The importance of stress roentgenograms made with the foot in inversion to determine the stability of the ankle joint has been repeatedly emphasized and deserves re-emphasis [2,4,6,14,22]. When the lateral ligaments of the ankle are torn the talus can be tilted inward (Figs. 18-A and 18-B). Leonard has shown that the degree of instability is determined by the number of fasciculi of the ligament that are torn. If the lateral ligaments do not rupture, the fibula may be fractured transversely at or just below the ankle joint (Fig. 19).

As inversion continues, the medial articular surface of the talus increases the pressure against the articular surface of the medial malleolus. The medial and superior surfaces of the talus form a wedge which strikes the mortise angle, causing a longitudinal split in the distal end of the tibia; the medial fragment includes the malleolus (Figs. 20-A and 20-B). In severe injuries, the tibial malleolus is displaced medially. The impact generally damages the articular surface at the mortise angle.

### *Compression Injuries*

Compression caused by a force applied in the longitudinal axis of the limb also results in characteristic injuries [1,2,9,11,16,18]. If the foot is in the neutral position and the impact is directed upward, the force is transmitted through the talus to the distal articular surface of the tibia, which is comminuted, compressed, and pushed directly upward. Because of the wedging effect of the talus the malleoli may be driven apart (Figs. 21-A through 21-C). If the foot is plantar flexed and the point of impact is on the metatarsal heads, the force is transmitted through the metatarsals and the posterior portion of the talus to the posterior articular margin of the tibia, which is fractured and displaced posteriorly and superiorly (Figs. 22-A and 22-B). If the foot is dorsiflexed and the impact is at the heel, the force is transmitted through the anterior surface of the talus to the anterior articular margin of the tibia, compressing it upward (Figs. 23-A and 23-B).

Special situations may arise; when the foot is dorsiflexed and the impact is on the metatarsals, the force is transmitted directly backward, causing a spreading injury of the mortise as the broad anterior portion of the talus is forced between the malleoli (Figs. 24-A and 24-B). Likewise, if the heel is everted at the moment of compression, the lateral portion of the distal articular surface of the tibia may be compressed (Fig. 25).

The impact of the talus on the tibia in compression injuries damages the articular surfaces to a greater extent than may be shown by roentgenograms.

Compound terms were not used in this report to describe injuries produced by more than one mechanism. In most injuries, one force will predominate and produce one or more of the characteristic pictures described. When more than one mechanism is involved and when each is of equal importance, complicated injuries will be produced containing the individual elements already described.

## SUMMARY

Adequate roentgenographic examination is essential to proper evaluation of injuries of the ankle joint, therefore appropriate roentgenograms which demonstrate the various fractures and the ligament injuries have been reproduced. The roentgenographic technique for demonstrating fractures is well known and practiced. However, the importance and significance of stress roentgenograms made of the foot in lateral

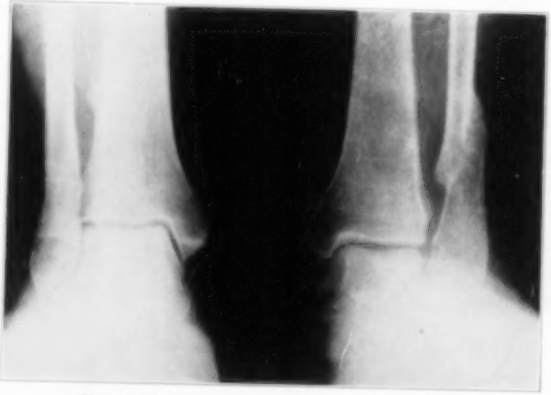


FIG. 16-A Fig. 16-B

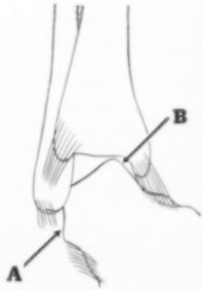


FIG. 17

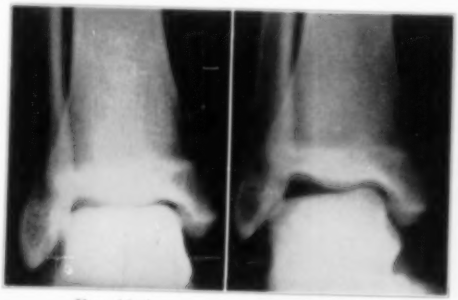


FIG. 18-A FIG. 18-B

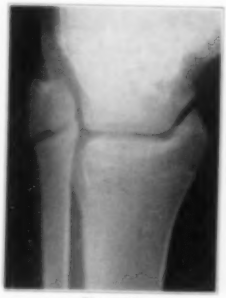


FIG. 19

Figs. 16-A and 16-B: Roentgenograms of an unusual eversion injury made with the patient standing.

Fig. 16-A: The normal ankle.

Fig. 16-B: The injured ankle. The roentgenogram shows a healed oblique fracture of distal fibular shaft with tibiofibular diastasis and a fracture of the distal end of the tibial malleolus. The calcaneus is markedly everted, while the talus is in normal position. This indicates that the calcaneotibial fibers of the deltoid ligament are torn but that the talotibial fibers are intact.

Fig. 17: Mechanism of injuries caused by inversion of the foot. (*A*) The inverting force tenses and may tear the anterior talofibular, posterior talofibular, and calcaneofibular ligaments, resulting in inversion instability; or it may cause by tension a transverse fracture of the fibular malleolus at or below the ankle joint. (*B*) The junction of the superior and medial articular surfaces of the talus then strikes the tibia at the mortise angle crushing its articular surface at this point and splitting the tibia longitudinally (see Figs. 20-A and 20-B).

Figs. 18-A and 18-B: Inversion instability.

Fig. 18-A: With the foot in the neutral position, the articular surfaces of the talus and the tibia are parallel.

Fig. 18-B: When the ankle is under inversion stress, the talus tilts medially, thus increasing the interval between the tibia and the talus laterally.

Fig. 19: An inversion fracture of the distal end of the fibula usually occurs at or below the level of the ankle joint. The fracture line is transverse and the fragments are not significantly displaced.

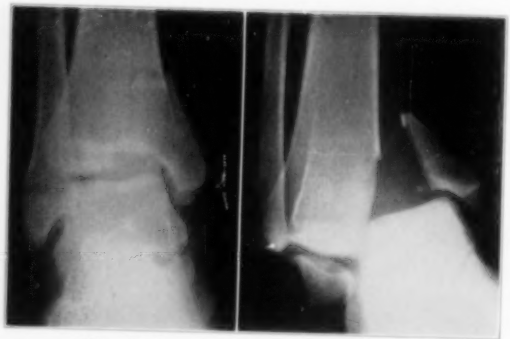


FIG. 20-A

FIG. 20-B

Figs. 20-A and 20-B: Inversion fractures of the tibia and fibula with slight displacement, and with complete dislocation. The fibular fracture is transverse. The talus is tilted medially and the junction of the medial and superior surfaces of the talus has struck the distal articular surface of the tibia, fracturing it longitudinally from the mortise angle to the medial tibial cortex. The articular surface of the tibia at the point of impact is destroyed, and the medial malleolar fragment and the talus may be displaced to different degrees.

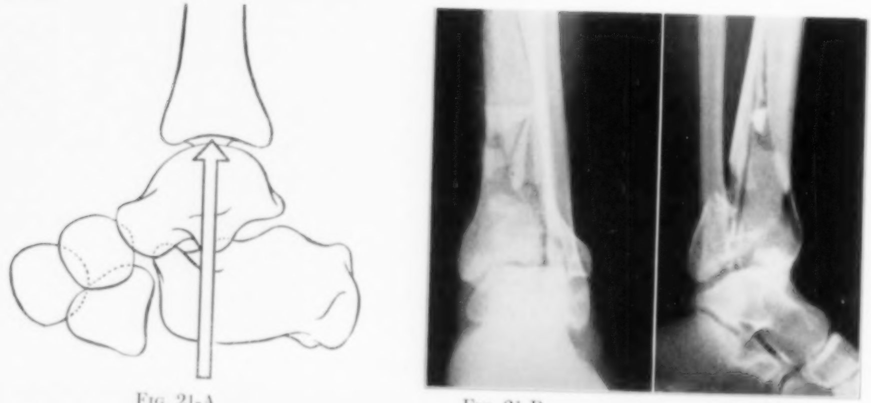


FIG. 21-A

FIG. 21-B

FIG. 21-C

Figs. 21-A, 21-B, and 21-C: Mechanism of fracture due to a compression force directed longitudinally upward.

Fig. 21-A: The impact is directed against the articular surface of the tibia and at right angles to it.

Fig. 21-B: The articular surface of the tibia is markedly comminuted, compressed, and displaced proximally. The anterior tubercle of the tibia is displaced laterally so that its border is lateral to the fibula. The fibular malleolus is also much longer than it should be with relation to the tibial malleolus. This indicates upward displacement of the distal tibial surface.

Fig. 21-C: The lateral roentgenogram confirms the marked comminution of the distal end of the tibia.

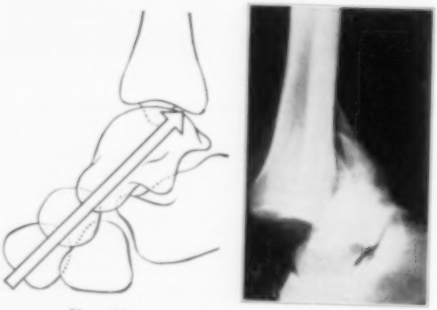


FIG. 22-A

FIG. 22-B

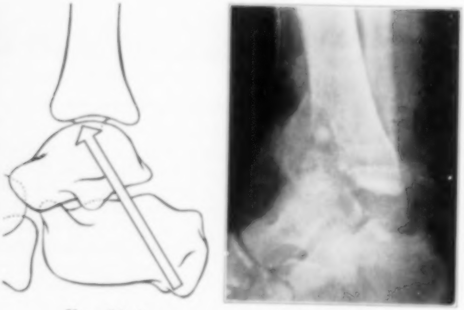


FIG. 23-A

FIG. 23-B

Figs. 22-A and 22-B: Compression fracture of the posterior margin of the distal end of the tibia due to a force directed upward and posteriorly.

Fig. 22-A: The impact is on the metatarsal heads and is transmitted upward and posteriorly.

Fig. 22-B: The talus strikes the posterior portion of the distal articular surface of the tibia, fracturing it and driving it upward and backward. This removes the downward projection of the posterior articular margin of the tibia and permits posterior dislocation of the foot.

Figs. 23-A and 23-B: Compression fracture of the anterior margin of the distal end of the tibia, due to a force directed upward and anteriorly.

Fig. 23-A: The force is directed upward and anteriorly from the calcaneus through the talus to strike the anterior portion of the distal articular surface of the tibia.

Fig. 23-B: Such an injury fractures the anterior margin of the distal articular surface of the tibia displacing it anteriorly and superiorly.

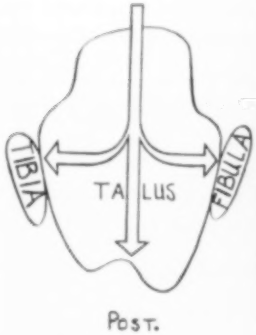


FIG. 24-A

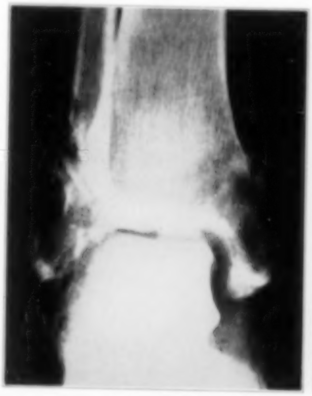


FIG. 24-B

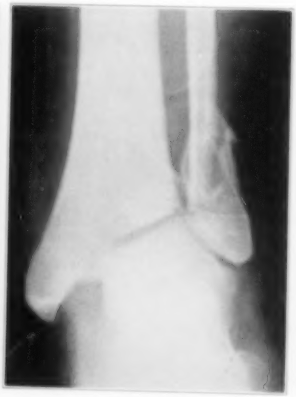


FIG. 25

Figs. 24-A and 24-B: Compression injury from a force directed posteriorly on the foot in the dorsiflexed position.

Fig. 24-A: The broad anterior portion of the body of the talus is pushed forcefully between the malleoli.

Fig. 24-B: This spreads the mortise so that the tibial malleolus is shifted medially slightly and the fibular malleolus is shifted laterally slightly.

Fig. 25: Compression fracture of the lateral portion of the distal articular surface of the tibia and of the distal end of the fibula when the calcaneus and talus are everted.

rotation and inversion have not been widely understood. For this reason, this report has laid great stress on the significance of ligament injuries and on the appropriate roentgenographic techniques for their diagnosis.

NOTE: The author is grateful to two men who made this work possible. The kindness and sound advice of Dr. Eliezer Bowie of New Orleans, Louisiana, started the author on this study while he was still in military service during World War II. Following the War, Dr. Leo Mayer has been a constant source of help.

I would like to express my thanks to Dr. Mayer for permission to reproduce many roentgenograms of his patients, to Dr. Michael S. Burman for Fig. 12, to the late Dr. Harry Sonnenschein for Fig. 14, and to Mr. Lee Gross for his time, effort, and patience in preparing the sketches.

## REFERENCES

1. ASHHURST, A. P. C., and BROMER, R. S.: Classification and Mechanism of Fractures of the Leg Bones Involving the Ankle. Based on a Study of Three Hundred Cases from the Episcopal Hospital. Arch. Surg., **4:** 51–129, 1922.
2. BONNIN, J. G.: Injuries to the Ankle. Ed. 1. New York, Grune and Stratton, 1950.
3. CICCONE, ROY, and RICHMAN, R. M.: The Mechanism of Injury and the Distribution of Three Thousand Fractures and Dislocations Caused by Parachute Jumping. J. Bone and Joint Surg., **30-A:** 77–97, Jan. 1948.
4. GOLDSTEIN, L. A.: Tear of the Lateral Ligament of the Ankle. New York State J. Med. **48:** 199–201, 1948.
5. HÖNIGSCHMIED, JOH.: Leichenexperimente über die Zerreissungen der Bänder im Sprunggelenk mit Rücksicht auf die Entstehung der indirecten Knöchelfracturen. Deutsche Zeitschr. f. Chir., **8:** 239–260, 1877.
6. KESTLER, O. C.: Traumatic Instability of the Ankle Joint. Am. J. Roentgenol., **60:** 498–504, 1948.
7. KLEIGER, BARNARD: Fractures of the Talus. J. Bone and Joint Surg., **30-A:** 735–744, July 1948.
8. KLEIGER, BARNARD: The Diagnosis and Treatment of Traumatic Lateral Ankle Instability. New York State J. Med., **54:** 2573–2577, 1954.
9. LAUGE, N.: Fractures of the Ankle. Analytic Historic Survey as the Basis of New Experimental Roentgenologic and Clinical Investigations. Arch. Surg., **56:** 259–317, 1948.

10. Lauge-Hansen, N.: "Ligamentous" Ankle Fractures. Diagnosis and Treatment. Acta Chir. Scandinavica, **97:** 544–550, 1949.
11. Lauge-Hansen, N.: Fractures of the Ankle. II. Combined Experimental-Surgical and Experimental-Roentgenologic Investigations. Arch. Surg., **60:** 957–985, 1950.
12. Le Fort, L.: Note sur une variété non décrite de fracture verticale de la malléole externe par arrachement. Bull. Gén. de Thérap. Méd. et Chir., **110:** 193–199, 1886.
13. Leitner, Baldo: Die Totalluxation des Talus und ihre Vorstufen. Ergeb. d. Chir. u. Orthop., **38:** 94–135, 1953.
14. Leonard, M. H.: Injuries of the Lateral Ligaments of the Ankle. J. Bone and Joint Surg., **31-A:** 373–377, Apr. 1949.
15. Lewin, Philip: The Foot and Ankle. Their Injuries, Diseases, Deformities, and Disabilities. Chap. 2, p. 53. Philadelphia, Lea and Febiger, 1940.
16. Magnusson, R.: On the Late Results in Non-Operated Cases of Malleolar Fractures: A Clinical Roentgenological Statistical Study. 1. Fractures by External Rotation. Acta Chir. Scandinavica, **90,** Supp. 84, 1944.
17. Magnusson, R.: On Late Results in Non-Operated Cases of Malleolar Fractures. Fractures by Pronation. Acta Chir. Scandinavica, **92:** 162–179, 1945.
18. Magnusson, R.: On Late Results in Non-Operated Cases of Malleolar Fractures; Fractures by Supination together with Survey of Late Results in Non-Operatively Treated Malleolar Fractures. Acta. Chir. Scandinavica, **92:** 259–277, 1945.
19. Maisonneuve, M. J. G.: Recherches sur la fracture du pérone. Arch. Gén. de Méd., Sér. 3. **7:** 165–187, 1840.
20. Shephard, E.: Tarsal Movements. J. Bone and Joint Surg., **33-B:** 258–263, May 1951.
21. Steindler, A.: Mechanics of Normal and Pathological Locomotion in Man, pp. 259–261. Springfield, Illinois, Charles C. Thomas, 1935.
22. Watson-Jones, Reginald: Fractures and Joint Injuries. Ed. 3, pp. 765–804. Baltimore, The Williams and Wilkins Company, 1946.
23. Wilson, M. J.; Michele, A. A.; and Jacobson, E. W.: Ankle Dislocations without Fracture. J. Bone and Joint Surg., **21:** 198–204, Jan. 1939.
24. Wood-Jones, Frederic: Structure and Function as Seen in the Foot. Chap. 12, pp. 101–123. Baltimore, The Williams and Wilkins Company, 1944.

# THE PATHOLOGY OF SLIPPING OF THE UPPER FEMORAL EPIPHYSIS

BY IGNACIO V. PONSETI, M.D., AND ROBERT McCLINTOCK, M.D., IOWA CITY, IOWA

*From the Department of Orthopaedic Surgery, State University of Iowa, Iowa City*

In a previous paper, we reported on lesions of the epiphyseal plate produced in rats by the incorporation in their diets of *Lathyrus odoratus* seeds [6]. These lesions led, in many instances, to epiphyseal slipping, and the experiments instigated the study of epiphyseal-plate lesions in human patients with upper femoral epiphysiolysis.

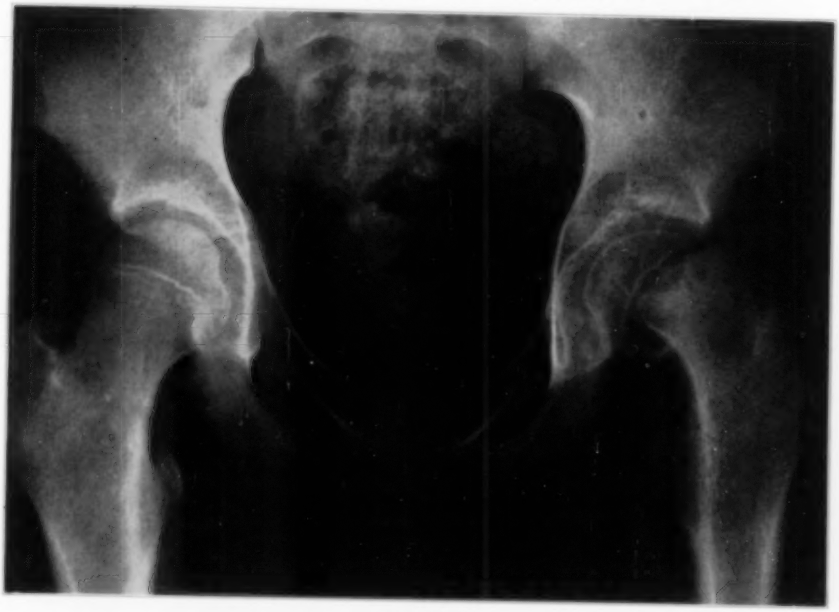


FIG. 1-A

Case 1. Roentgenogram of the pelvis of an eleven-year-old girl with an acute, severe slipping of the upper femoral epiphysis of the left hip. The right hip appeared to be normal.

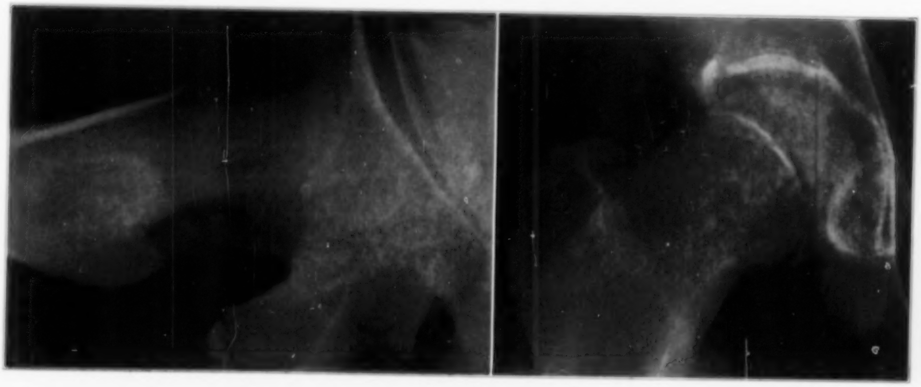


FIG. 1-B

Lateral and anterior posterior roentgenograms of the right hip made one year after the roentgenogram in Fig. 1-A. There is a slight degree of epiphyseal slipping.

The object of this paper is to describe the pathological lesions of the upper femoral epiphyseal plates in three patients with clinical and roentgenographic findings typical of the early stages of slipping of the upper femoral epiphysis. Core biopsies of the femoral neck and head were done with a Phemister punch, one centimeter in diameter, which was introduced through the outer aspect of the upper femoral shaft into the center of the femoral neck and head. This was followed by the insertion of three threaded pins—the standard treatment in this Clinic for minor degrees of slipping of the upper femoral epiphysis[5]. The biopsy specimens thus obtained usually broke at the junction of the epiphyseal plate with the metaphysis. Both pieces of bone were wrapped in gauze and,

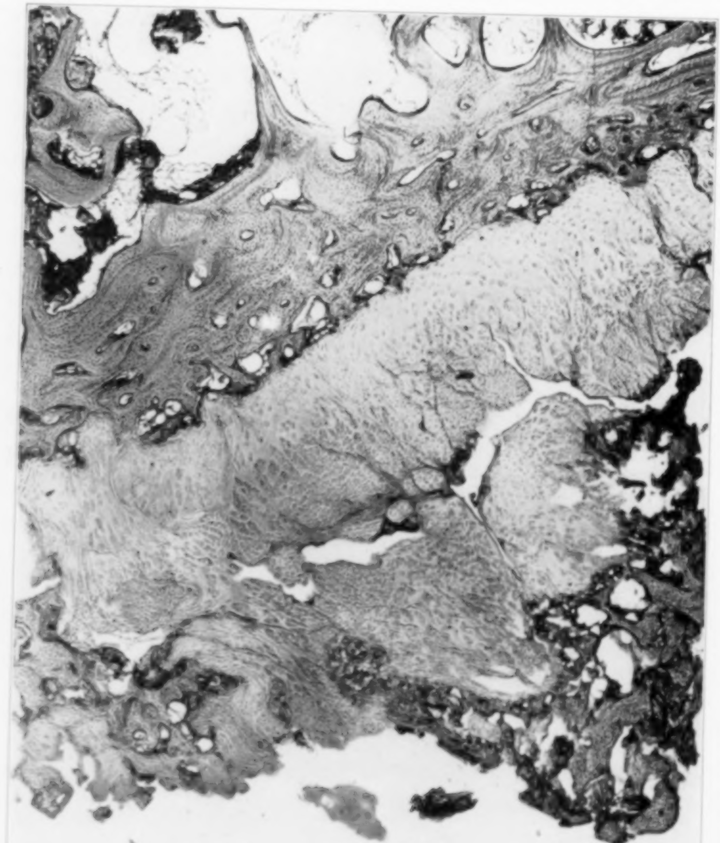


Fig. 1-C

Photomicrograph of the biopsy specimen from the right hip at the level of the epiphyseal plate (× 20). The epiphysis is in the upper part of the picture and the diaphysis is in the lower part. The biopsy specimen broke at the junction of the epiphyseal plate with the metaphysis. The epiphyseal plate is very wide and an extensive cleft is seen extending through the middle (hematoxylin and eosin).

thus, were kept in their anatomical position during the decalcification and the embedding in celloidin. Slides were obtained from the blocks and were stained with hematoxylin and eosin.

CASE 1. A. R. An eleven-year-old white girl was first seen in the State University of Iowa Hospital in November 1952. Two months prior to admission she had been hit on the left side while playing and some pain and a limp developed in the left hip. Three weeks later she had fallen on the floor on her left side and had severe pain in her left hip which made weight-bearing impossible.

On physical examination, the girl was of normal build, was well nourished, and appeared to be normal except for the left lower extremity. The left hip was in 25 degrees of external rotation; there was a 50-degree

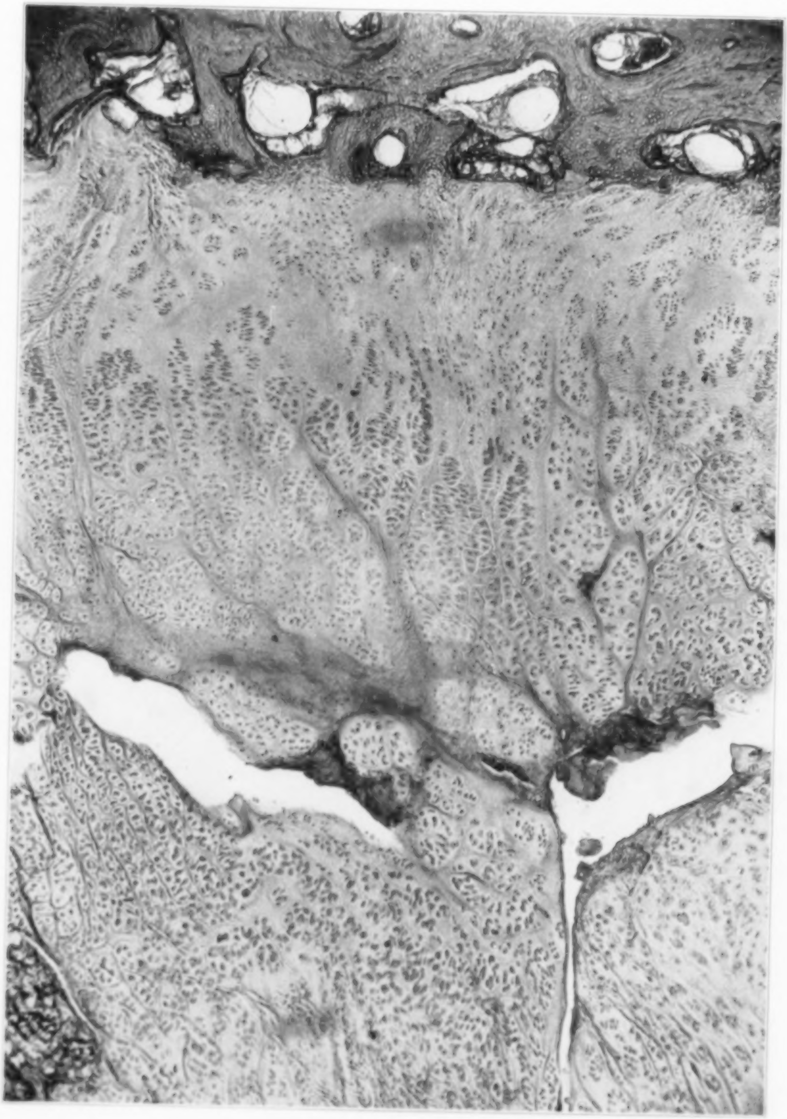


FIG. 1-D

Photomicrograph of the epiphyseal plate (× 50). The cartilage cells are disorderly arranged and are separated by fibrillated septa. A large cleft is seen filled with small amounts of amorphous débris (hematoxylin and eosin).

flexion contracture. The hip muscles were in spasm, and all motions of the left hip were painful. The roentgenograms revealed complete slipping of the left capital femoral epiphysis (Fig. 1-A). Open reduction was done, and the head was fixed with three threaded pins. Follow-up roentgenograms revealed aseptic necrosis of the femoral head; this was treated in June 1953 by the insertion of a bone graft through the femoral neck into the femoral head. She walked with crutches until June 1954, when the roentgenograms revealed satisfactory replacement of the necrotic bone of the left femoral head; she was then allowed to bear weight.

In September 1954, slight intermittent pain developed in the right hip. When she was examined one month later, it was noticed that she had no internal rotation in the right hip and that, on flexion, the thigh went into external rotation. The roentgenograms revealed a slight degree of slipping of the epiphysis of the right hip (Fig. 1-B). On October 15, 1954, a biopsy specimen was taken from the right femoral head and neck, and three threaded pins were inserted.

She recovered well from the operation. One month later, however, acute rheumatic fever developed. When she was last seen in March 1955, the rheumatic fever had become quiescent and she was ambulatory. She had no complaints referable to the right hip, but she still limped on the left side. The range of motion of the right hip was normal; she had marked restriction of motion in the left hip.

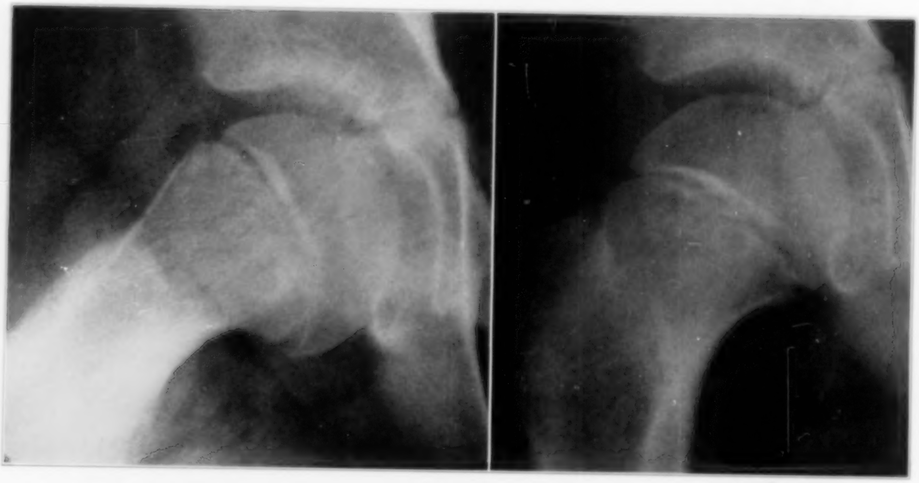


FIG. 2-A

Case 2. Lateral and anterior posterior roentgenograms of the right hip reveal a minimal amount of epiphyseal slipping.

### *Laboratory Examination*

Laboratory examinations showed values within normal limits for the following: hemoglobin, erythrocyte count, leukocyte count, sedimentation rate, plasma albumin and globulin, serum calcium, phosphorus and alkaline phosphatase.

The serum vitamin-E level was 0.52 milligram per hundred cubic centimeters. Plasma protein-bound iodine was 5.1 micrograms per 100 cubic centimeters.

Urine was negative for albumin and sugar.

The twenty-four-hour urinary excretion of amino acids was determined by paper chromatography, phenol and lutidine being used as solvents. Thirteen amino acids or their derivatives were observed in the patterns. Histidine, taurine, alanine, glutamine, and tyrosine were present in the greatest amount (134, 131, 128, 105, and 99 milligrams per twenty-four hours, respectively). The total urinary amino-acid nitrogen, by chemical analysis, was 0.198 gram per twenty-four hours.

Urinary 17-ketosteroid excretion was 4.3 milligrams per twenty-four hours (seven milligrams per gram of creatinine). Gonadotropins were not detected in the urine. Vaginal smear revealed intermediate and precornified type cells indicative of low estrogen level of the premenarche period.

Roentgenographic studies of the wrist, done in February 1955 when the patient was thirteen years and one month old, showed her bone age, according to Todd's Atlas, to be thirteen years and nine months.

### *Histological Examination* (Figs. 1-C and 1-D)

The bone and the bone marrow of the femoral head and neck were normal. The joint cartilage was not unusual. The epiphyseal plate was very wide. The cartilage cells appeared to be normal; but, instead of being lined up in orderly rows, they were grouped in clusters. These clusters were separated by fibrillated septa, some of which were very wide and stained deeply with eosin. There were extensive clefts extending through the middle of the epiphyseal plate. These clefts were partially filled with small amounts of eosin-stained amorphous débris and a few small clusters of cartilage cells. Adjacent to the metaphysis, there were areas in which endochondral ossification appeared to proceed normally whereas, in other areas, it had ceased completely. This apparently accounted for the irregular outline of the epiphyseal plate on the metaphyseal side. Areas of endochondral ossification appeared deep in the neck. There were islands of cartilage cells in between some of the bone trabeculae of the metaphysis. No osteoid tissue was present.

Case 2. N. M. A white boy, eleven and one-half years old, was first seen at the State University of

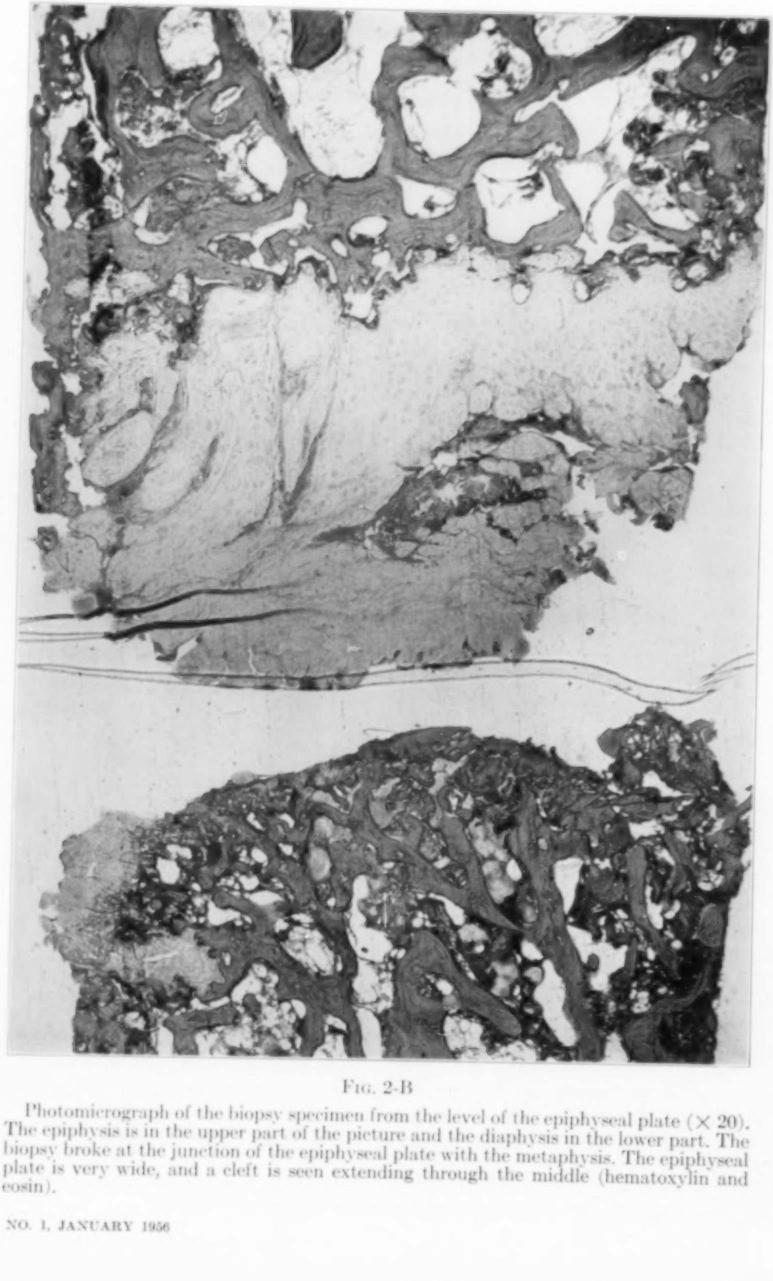


Fig. 2-B

Photomicrograph of the biopsy specimen from the level of the epiphyseal plate (× 20). The epiphysis is in the upper part of the picture and the diaphysis in the lower part. The biopsy broke at the junction of the epiphyseal plate with the metaphysis. The epiphyseal plate is very wide, and a cleft is seen extending through the middle (hematoxylin and eosin).

Iowa Hospital on November 11, 1954. He complained of pain in the right hip and had had difficulty in walking of six months' duration. These symptoms had come on after he had fallen from a swing. His parents had noticed immediately after this fall that the boy was limping and was unable to rotate his right leg internally.

This boy appeared somewhat obese. He was five feet tall and weighed 140 pounds. Internal rotation of the right hip was limited to 15 degrees, whereas in the left hip it was free to 30 degrees. The external rotation of the right hip was free to 60 degrees. On flexion of the right hip, the thigh went into external rotation. The roentgenograms revealed a widened capital femoral epiphyseal plate on the right, with a minimal amount of slipping (Fig. 2-A). Three days after admission, a core biopsy of the right femoral head and neck was done, and three threaded pins were inserted to fix the femoral head. Following the operation, the patient was advised to walk with crutches without bearing weight on the right leg. When he was examined in March 1955, he had no pain in the hip, and the range of motion in the hip was normal. He was allowed weight-bearing without crutches.

*Laboratory Examinations*

Laboratory examinations showed values within normal limits for the following: hemoglobin, erythrocyte count, leukocyte count, sedimentation rate, plasma albumin and globulin, serum calcium, phosphorus, and alkaline phosphatase.

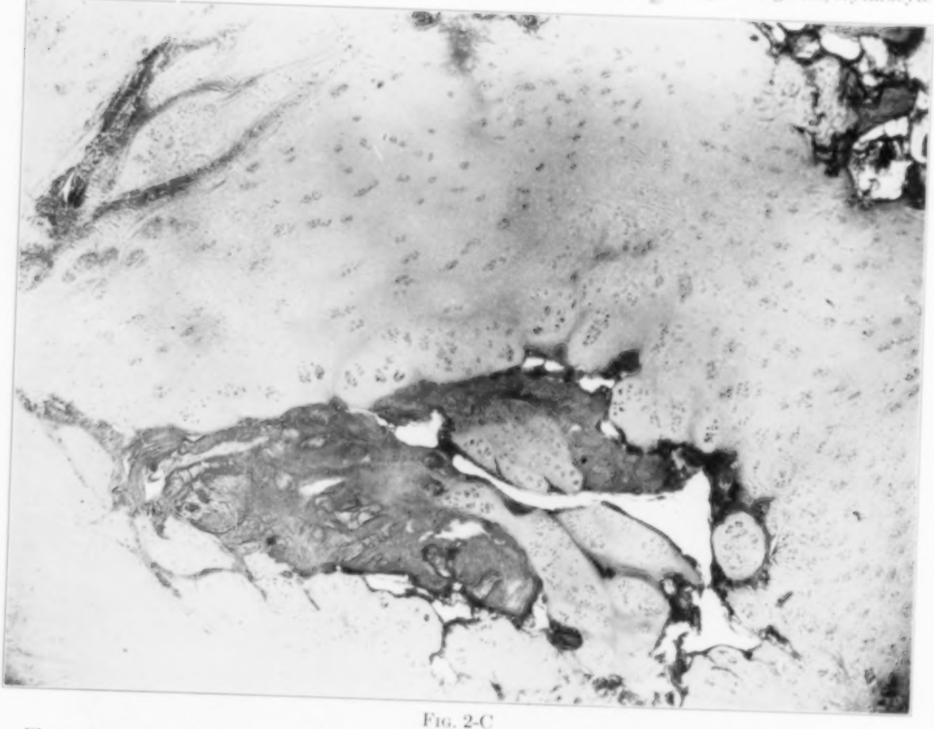


FIG. 2-C

Photomicrograph of the upper femoral epiphyseal plate (× 46). A large cleft in the epiphyseal plate completely filled with an amorphous débris is shown. The cartilage cells are disarranged (hematoxylin and eosin).

The serum vitamin-E level was 0.30 milligram per 100 cubic centimeters.

Urine was negative for albumin and sugar.

The twenty-four-hour urinary excretion of amino acids was determined by paper chromatography, phenol and lutidine being used as solvents. Nine amino acids or their derivatives were observed in the patterns. Taurine, histidine, and serine were present in the greatest amount (204, 178, and 163 milligrams per twenty-four hours, respectively). The total urinary amino-acid nitrogen, by chemical analysis, was 0.325 gram per twenty-four hours.

Urinary 17-ketosteroid excretion was 3.5 milligrams per twenty-four hours (four milligrams per gram of creatinine).

Roentgenograms of the wrist made in March 1955, when the patient was twelve years old, showed his bone age, according to Todd's Atlas, to be thirteen years and nine months.

*Histological Examination* (Figs. 2-B, 2-C, 2-D, and 2-E)

The histological appearance of the biopsy specimen from this patient was similar to that in Case 1. A large cleft in the epiphyseal plate was almost completely filled with amorphous eosin-stained débris. Blood vessels and extravasated blood were seen in the cleft and surrounded some of the clusters of cartilage cells. There were also amorphous débris and clumps of cartilage cells in between the bone trabeculae of the metaphysis in areas close to the epiphyseal plate (Fig. 2-E). The line of endochondral ossification had been distorted by the trauma at the time the biopsy was done. A small area was well preserved and showed active endochondral ossification. Adjacent to this area of endochondral ossification, there was a large mass of disarranged cartilage penetrating deep into the metaphysis (Fig. 2-D).

CASE 3. A. G. A fourteen-year-old white boy was admitted to the State University of Iowa Hospital on April 22, 1954. He complained of pain in the right hip of four months' duration. This pain had had an insidious onset, and there was no definite history of trauma. The family history was interesting in that the boy's father, at forty years of age, had had an "idiopathic" aseptic necrosis of the right hip which had been treated by bone-grafting.

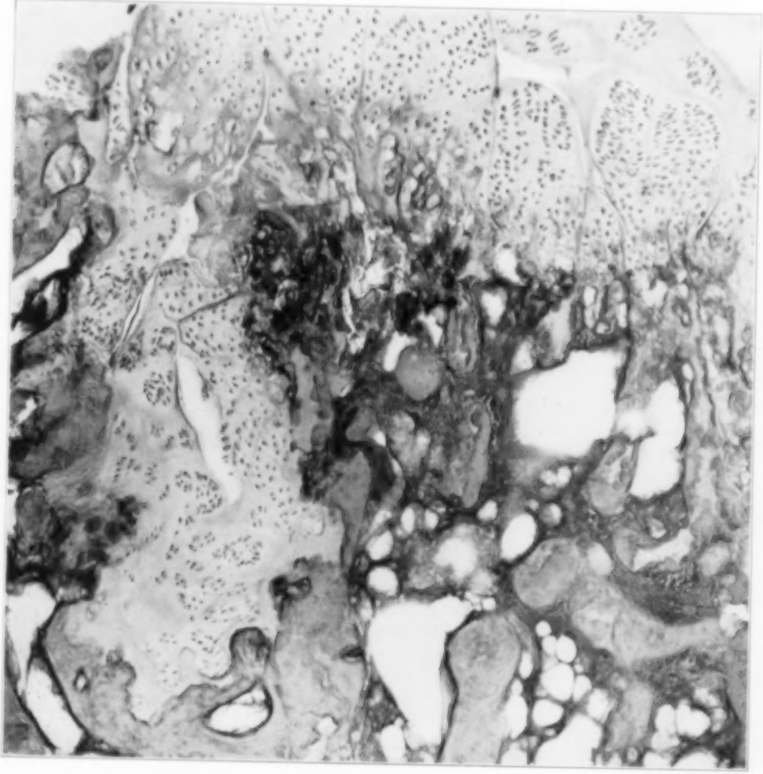


FIG. 2-D

Photomicrograph of an area of endochondral ossification observed in the metaphyseal side of the specimen (× 50). The cartilage cells are separated by clefts, and there is a large tongue of disarranged cartilage which has penetrated deep into the metaphysis (hematoxylin and eosin).

On examination, this boy, five feet, nine and a half inches tall, weighed 250 pounds, having lost thirty pounds in the last nine months. His penis and testes were small. He walked with an antalgic gait on the right. The right leg could not be internally rotated beyond neutral, whereas external rotation was free to 90 degrees. As the right hip was flexed past 90 degrees, the leg went into external rotation. There was neither pain nor restriction of motion in the left hip. Roentgenograms of the pelvis, with lateral views of the hips, demonstrated an early slipping of the epiphysis on the right side, with minimal displacement. Four days following admission, three threaded pins were inserted into the right femoral head. Two weeks after the operation the

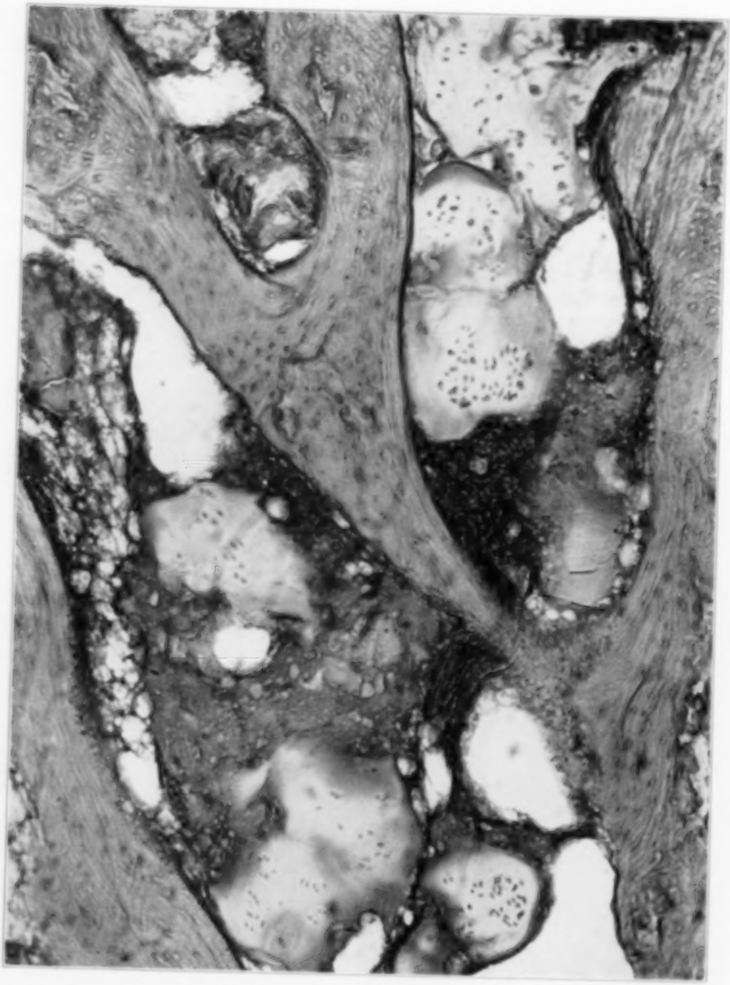


FIG. 2-E

Photomicrograph of a specimen from the metaphysis (× 100). Clumps of cartilage cells and amorphous débris are seen between the bone trabeculae (hematoxylin and eosin).

patient was allowed to be up with crutches, without bearing weight on the right leg. In October 1954, the crutches were discarded. A few weeks later the patient noticed some aching in the left hip after exercise; this persisted until January 1955. At that time it was noticed that internal rotation of both hips was limited to 20 degrees. Roentgenograms showed that the left upper femoral epiphyseal plate was wide and somewhat irregular, without evidence of slipping (Fig. 3-A). The epiphyseal line of the greater trochanter was wide and irregular, also. On February 4, 1955, a biopsy of the left capital femoral epiphysis was performed. Following this, the femoral head was fixed by the insertion of three threaded pins.

### *Laboratory Examinations*

Laboratory examinations showed values within normal limits for the following: hemoglobin, erythrocyte count, leukocyte count, sedimentation rate, plasma albumin and globulin, serum calcium, phosphorus, and alkaline phosphatase.

The serum vitamin-E level was 0.62 milligram per 100 cubic centimeters. Plasma protein-bound iodine was 6.4 micrograms per 100 cubic centimeters.

Urine was negative for albumin and sugar.

The twenty-four-hour urinary excretion of amino acids was determined by paper chromatography, phenol and lutidine being used as solvents. Seventeen amino acids and their derivatives were observed in the patterns. Taurine, glutamine, serine, and histidine were observed in the greatest amount (334, 248, 198, and 182 milligrams per twenty-four hours, respectively). (The value for taurine is the highest as yet recorded in our laboratory. Interestingly, this boy is the largest boy we have studied.) The total urinary amino-acid nitrogen, by chemical analysis, was 0.417 gram per twenty-four hours.

Urinary 17-ketosteroid excretion was 8.4 milligrams per twenty-four hours (five milligrams per gram of creatinine).

Roentgenograms of the wrist made in May 1955, when the patient was fifteen years and nine months old, showed his bone age, according to Todd's Atlas, to be fourteen years and nine months.

*Histological Examination* (Figs. 3-B and 3-C)

The biopsy specimen broke through the middle of the epiphyseal plate. However, on histological examination it could be observed that in a large area the cartilage cells were arranged in orderly rows and that the endochondral ossification was proceeding normally. In another area the epiphyseal plate was very wide. Here the cartilage cells were clumped in clusters separated by small clefts, some of which were penetrated by blood vessels. Some islands of cartilage cells were seen in between the bone trabeculae of both the epiphysis and the metaphysis in areas close to the epiphyseal plate. Otherwise, the bone and joint cartilage were normal.

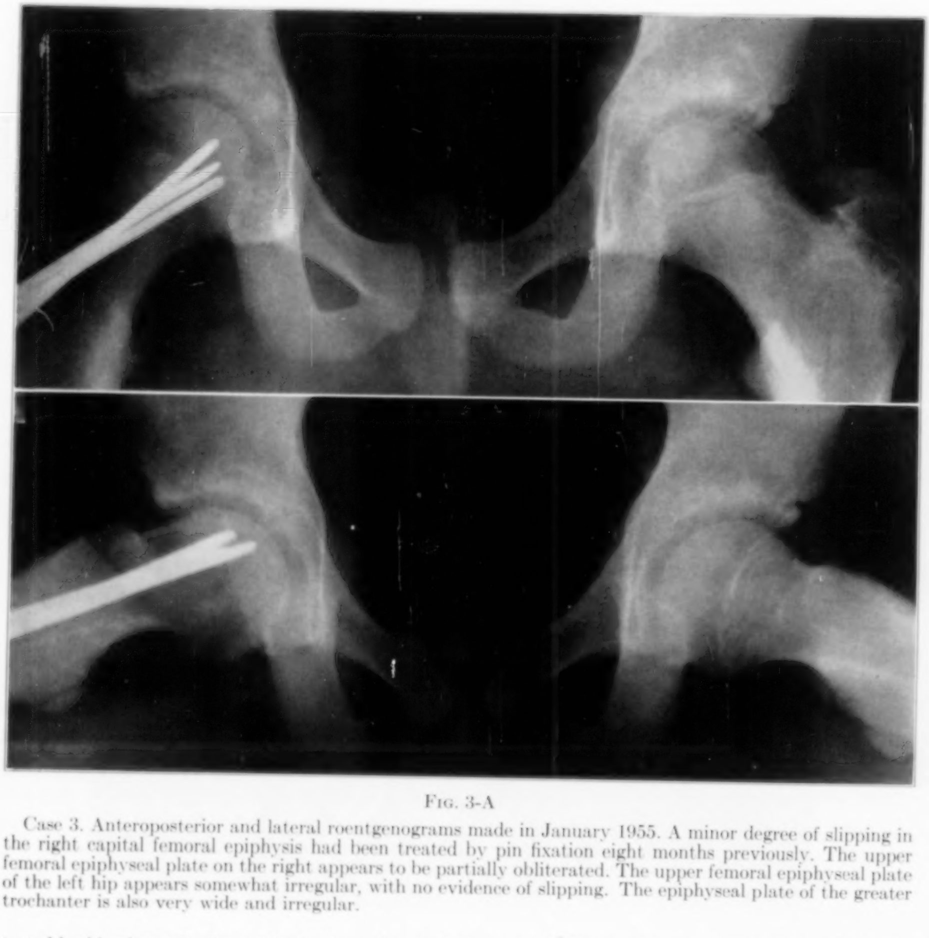


FIG. 3-A

Case 3. Anteroposterior and lateral roentgenograms made in January 1955. A minor degree of slipping in the right capital femoral epiphysis had been treated by pin fixation eight months previously. The upper femoral epiphyseal plate on the right appears to be partially obliterated. The upper femoral epiphyseal plate of the left hip appears somewhat irregular, with no evidence of slipping. The epiphyseal plate of the greater trochanter is also very wide and irregular.

On the basis of this biopsy specimen, it can be stated that in this hip, in which no slipping had been detected in the roentgenograms, the epiphyseal plate was normal in some areas and in other areas the same lesion observed in the other two patients was seen.

## DISCUSSION

The joint cartilage and bone of the femoral head and neck appeared to be normal in the three cases presented. The epiphyseal plate was wide and was greatly disrupted. The rows of proliferating cartilage cells were disorganized, and the cells were grouped in clusters. The cartilage matrix seemed to have lost its cohesion. It was fibrillated; large clefts occurred in areas of the plate, and necrotic débris was seen in some of the clefts. Occasionally blood vessels had invaded these disrupted areas. Endochondral ossification was interrupted in many areas but was progressing in others. Islands of cartilage cells were seen in the metaphysis. There were no signs of rickets, osteomalacia, osteoporosis, or infection. It appears that the primary lesion in such cases is loss of cohesion of the cartilage matrix, presumably due to an alteration in the chemical composition of the

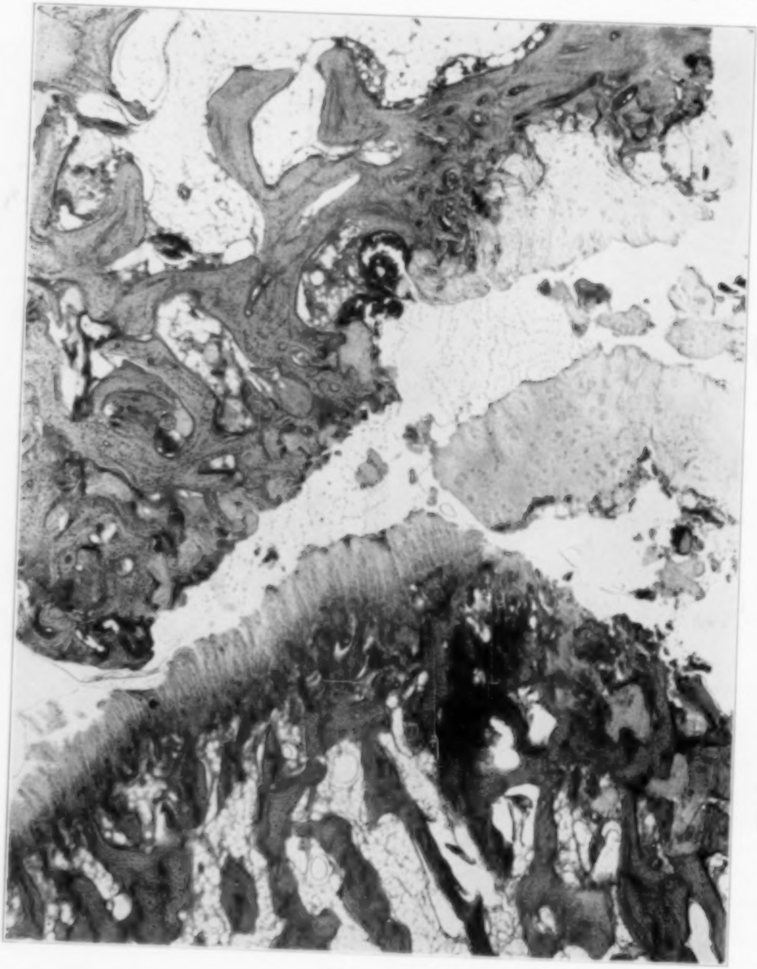


FIG. 3-B

Photomicrograph of the biopsy specimen from the left hip at the level of the epiphyseal plate (× 22.5). The epiphysis is in the upper part of the picture and the diaphysis in the lower part. The biopsy broke through the middle of the epiphyseal plate. In the left half of the photograph, the cartilage cells are arranged in orderly rows and endochondral ossification was proceeding normally. In the right half of the photograph, the epiphyseal plate appears to be very wide and the cells are grouped in clusters (hematoxylin and eosin).

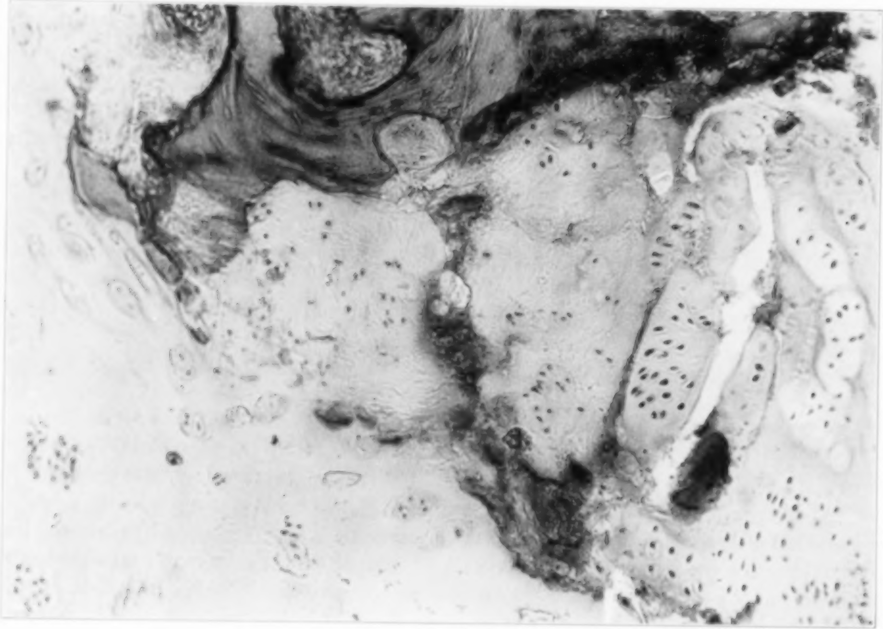


FIG. 3-C

Photomicrograph of the upper portion of the epiphyseal plate (× 80). An area of degenerated cartilage penetrated by blood vessels is seen in the middle of the picture. The cartilage cells are clumped in clusters (hematoxylin and eosin).

ground substance. This weakness of the ground substance results in cleft formation, and there is reactive cartilage-cell proliferation. It may be assumed that this epiphyseal-plate lesion results in loss of strength of the plate and that it is mainly responsible for the epiphyseal slipping.

Skeletal surveys of patients with slipped upper femoral epiphysis have shown some widening and irregularities in the outlines of other epiphyseal plates which suggest that the lesion is not restricted to the upper portion of the femur.

Analysis for hemoglobin, plasma albumin and globulin, serum calcium, phosphorus, alkaline phosphatase, and protein-bound iodine for the three subjects showed no marked changes from the normal. Erythrocyte and leukocyte counts were also within the normal range. In each case, serum vitamin-E levels were below the normal range of 0.8 to 1.2 milligrams per 100 cubic centimeters.

Chromatographic patterns of urinary amino acids, with phenol and lutidine being used as reagents, showed consistently high values for taurine, histidine, and serine. Taurine is often excreted by normal children, but usually in amounts under thirty milligrams daily. Histidine is excreted in relatively small amounts, if at all, by normal persons. Serine is commonly found in the urine but in amounts usually well under 100 milligrams daily. The total amino-acid nitrogen values of the urine of the three subjects studied here are not abnormal. The distribution, rather than the quantity of amino acids, is altered. These findings are similar to the ones observed in children with adolescent scoliosis [7].

The epiphyseal-plate lesions seen in these three patients are similar to the lesions observed in the epiphyseal plates of rats fed diets containing sweet-pea seeds [6]. The active agent in these seeds which is responsible for the skeletal lesions is $\beta$-aminopropionitrile [9]. It has been shown that other aminonitriles can produce similar lesions in rats and that chicks and amphibia are very sensitive to these compounds[1,9]. In a recent paper, Dasler has stated that $\beta$-mercaptoethylamine also produces in rats the typical skeletal lesions caused by the sweet-pea seeds[2]. The similarity of the epiphyseal-plate lesions in human patients and in the experimental animals does not, of course, imply a similar pathogenesis. It appears from our studies that the underlying cause of epiphysiolysis in human beings is a metabolic disturbance. We do not know if this disturbance is related to an inability of the organism to neutralize nitriles which may be produced in the catabolism of the proteins or if it is related to some other metabolic aberration.

The three patients studied did not appear to have any endocrine anomaly. It is realized, however, that a hormonal imbalance, as suggested by Harris, a rapid increase in height and weight, and trauma may be contributing factors to epiphysiolysis in some patients.

Lacroix and Verbrugge published, in 1951, a pathological study of the upper end of the femur obtained, at the time of a Whitman reconstruction operation, from two patients with slipped epiphysis. The patients were sixteen years of age when the specimens were obtained and had had progressive epiphysiolysis since the age of thirteen. Large areas of vascular fibrous tissue and fibrocartilage were seen to occupy the site of the epiphyseal plate, although remnants of epiphyseal cartilage and areas of endochondral ossification were still present. It seems to us that these cases represented a very late stage of the disease and that the fibrous-tissue replacement was secondary to the extensive disruption of the epiphyseal plate due to the slipping. The extensive cleft observed in the central portion of the specimen of Case 1 is of interest and it may represent the remnants of a cleft in the epiphyseal plate which became completely ossified in this area.

Epiphyseal-plate lesions, similar to those described here, were observed by Sutro in three cases. His first case is of especial interest. It was that of an eleven-year-old girl with an acute slipping of the right femoral head and an old lesion of the left hip which the author considered to be a healed slipped capital femoral epiphysis. A large portion of the left femoral head and a small portion of the neck of the femur were resected in the process of doing a reconstruction operation. This was the specimen studied by the author. The photograph of the roentgenogram of this left hip shows a flattened and somewhat sclerotic femoral head mushroomed over a very wide femoral neck without any suggestion of epiphyseal slipping. The photographs of the gross sections of the femoral head do not show any degree of epiphyseal slipping. Some necrotic bone was seen in one of the sections. It seems to us that this lesion in the left femoral head represents healed Perthes disease rather than a slipped epiphysis. The roentgenograms of the other two cases presented in Sutro's paper show the characteristic picture of slipped epiphysis. The important point is that similar epiphyseal plate lesions were observed in the last two cases of slipped epiphysis as in the left hip of the first case which was, as we believe, Perthes disease. From our animal experiments, we have surmised that a similar lesion in the upper femoral epiphysis is responsible for slipped epiphyses and for Perthes disease. This conjecture has been verified recently with the findings in core biopsies obtained from patients with Legg-Perthes disease. These studies will be presented in another paper.

## SUMMARY

Biopsies specimens from the femoral neck and head of three patients with early slipping of the upper femoral epiphysis were obtained. The epiphyseal plate in these patients was found to be wide and greatly disrupted, and clefts had occurred in areas of the plate. There were no signs of rickets, osteomalacia, osteoporosis, or infection. The epiphyseal-plate lesion appears to be due to loss of cohesion of the cartilage matrix, presumably caused by an alteration of the chemical composition of the ground substance. This lesion appears to be mainly responsible for the epiphyseal slipping. Metabolic studies of these children have shown an abnormality in the protein metabolism similar to the one

found in children with adolescent scoliosis. The epiphyseal-plate lesions in these patients were similar to the lesions observed in experimental animals fed minimal amounts of aminonitriles.

## REFERENCES

1. Chang, C. Y.; Witschi, Emil; and Ponseti, I. V.: Teratologic Development in Xenopus Larvae Caused by Sweet Pea Seeds (Lathyrus odoratus) and Their Extracts. Anat. Rec., **120:** 816–817, 1954.
2. Dasler, Waldemar: Production of Experimental Lathyrism in the Rat by Two Different Beta-substituted Ethylamines. Proc. Soc. Exper. Biol. and Med., **88:** 196–199, 1955.
3. Harris, W. R.: The Endocrine Basis for Slipping of the Upper Femoral Epiphysis. J. Bone and Joint Surg., **32-B:** 5–11, Feb. 1950.
4. Lacroix, Pierre, and Verbrugge, Jean: Slipping of the Upper Femoral Epiphysis; Pathological Study. J. Bone and Joint Surg., **33-A:** 371–381, Apr. 1951.
5. Ponseti, I. V., and Barta, C. K.: Evaluation of Treatment of Slipping of the Capital Femoral Epiphysis. Surg., Gynec., and Obstet., **86:** 87–97, 1948.
6. Ponseti, I. V., and Shepard, R. S.: Lesions of the Skeleton and of Other Mesodermal Tissues in Rats Fed Sweet Pea (*Lathyrus odoratus*) Seeds. J. Bone and Joint Surg., **36-A:** 1031–1058, Oct. 1954.
7. Stearns, Genevieve; Chen, J.-Y. T.; McKinley, J. B.; and Ponseti, I. V.: Metabolic Studies of Children with Idiopathic Scoliosis. J. Bone and Joint Surg., **37-A:** 1028–1034, Oct. 1955.
8. Sutro, C. J.: Slipping of the Capital Epiphysis of the Femur in Adolescence. Arch. Surg., **31:** 345–360, 1935.
9. Wawzonek, S.; Ponseti, I. V.; Shepard, R. S.; and Wiedenmann, L. G.: Epiphyseal Plate Lesions, Degenerative Arthritis, and Dissecting Aneurysm of the Aorta Produced by Aminonitriles. Science, **121:** 63–65, 1955.

---

## DISCUSSION

### Posterior Arthrodesis of the Ankle

(*Continued from Page 58*)

especially practical if, after operation, there is a need to improve the position of the foot, since this can be done quite easily. This posterior arthrodesis will be well received.

Dr. Staples (closing): In regard to the question of whether bone of local origin or whether bone from the ilium is better, it depends on the surgeon's preference and the situation at hand. Ordinarily, in complicated cases, I prefer less local dissection, and I prefer to use bone which I can shape exactly, which comes from another source. I would like to repeat that this approach is not recommended for routine application, but, only in certain circumstances,—when there is perhaps scarring anteriorly and when the talocalcaneal joint should be included in the fusion area. The posterior approach simplifies the operative task.

# A STUDY OF EXPERIMENTAL TRAUMA TO THE DISTAL FEMORAL EPIPHYSIS IN RABBITS * †

BY LEE T. FORD, M.D., AND J. ALBERT KEY**, M.D., ST. LOUIS, MISSOURI

*From the Department of Surgery, Washington University School of Medicine, and Barnes and Wohl Hospitals, St. Louis*

The important role of the epiphyseal cartilage in the longitudinal growth of a long bone is universally recognized. According to Phemister, Stephen Hale, in 1727, first showed experimentally in chickens that growth of the bone occurs at the end of the bone. Hale had drilled two holes in the shaft of a chicken bone and found, two months later, that there was no change in the space between the holes, although the entire bone had grown one inch in length.

Gatewood and Mullen, in 1927, showed that all longitudinal growth in rabbits occurs in the epiphysis. They placed multiple lead markers one centimeter apart in a long bone of a growing rabbit and found, as had Hale, no change in the position of the markers in the shaft.

Hellstadius [5] advanced an unusual and not generally accepted opinion that longitudinal growth will occur in the absence of an epiphysis. Using seven rabbits, he resected the distal ulnar epiphysis and found what he considered continued growth in length of one-third or less of normal in five rabbits. Unfortunately, he showed sketches of the bones and not roentgenograms. Two animals showed no growth when he resected the entire distal half of the ulna. The authors feel that what Hellstadius considered growth in length was merely accretion or spindle-like formation of new bone at the end of the shaft and not true growth in length of the shaft.

Lacroix gave an interesting, but theoretical, reason for any growth found in Hellstadius' animals. He reasoned that a new epiphyseal cartilage had formed to produce the growth and had then fused and disappeared. Hellstadius [6] answered this in a later article. He concluded that the extra growth he had described in his animals in the absence of an epiphysis was an inherent property of the shaft of the bone. There is no question in our minds but that it is true that the epiphyseal cartilage is all important to growth in the length of long bones.

It has been known for years that many factors can alter this growth. Haas [2], in 1917, described careful experiments on forty-five young dogs; he emphasized the rich vascular supply about the epiphyses in the metatarsals and tibiae of the animals and noted that the vascular supply diminished when growth ceased. He observed the growth of long bones after varying degrees of surgical trauma to the epiphyses. A simple longitudinal incision down to an epiphysis did not significantly alter the blood supply, and there was no effect upon growth; but, if the tissues had been stripped from an epiphysis, there was some interference with growth. He stressed the importance in surgery on bones of protecting the blood supply of an epiphysis. From later work on rabbits [3], he showed that: (1) metal pins could be passed across an epiphyseal cartilage and would not interfere with growth if they were removed early; (2) pins in the diaphysis caused no restriction; (3) pins crossing the metaphysis just above the epiphyseal plate caused variable growth restriction; (4) pins placed diagonally across one side of the epiphyseal plate caused angulation and some lag in growth; and (5) pins placed straight across the plate would cause definite restriction of growth when they were allowed to remain.

---

* Read at the Orthopaedic Section of the Surgical Forum of the American College of Surgeons, Atlantic City, New Jersey, November 17, 1954.

† This investigation was supported by a research grant from the National Institutes of Health, Public Health Service.

** Deceased.

In 1933, Speed and Macey described twelve fractures of the humeral condyle in children which they had treated by open reduction and in which they had used small wire nails for fixation. These nails had crossed the epiphyseal line, but, if they were removed after several weeks, they caused no significant growth interference.

Many factors, other than those already mentioned, can disturb the function of the epiphyseal cartilage. Phemister pointed this out and mentioned fracture, epiphyseal separation, joint infection, bone infection, tumor, paralysis, and congenital disturbance. In his paper, he described the procedure of epiphyseodesis and reported twenty cases in which it had been carried out. Hatt reported that the distal femoral epiphysis can be crossed by a cortical bone graft in performing an arthrodesis of the knee in children without the arrest of the growth of the femur.

The authors have wondered which part of an epiphyseal cartilage, if any, is of the most importance in the function of producing longitudinal growth. They have carried out on rabbit femora three types of experimental trauma to the distal epiphysis. All experiments were done on the right femur, the left femur being used as a control.

An attempt was made to find out whether the central portion or the peripheral portion was of more importance in growth function. All rabbits used were from three to four weeks old at the time of surgery. Anaesthesia for these small animals was a problem, and seventeen out of forty-eight animals were lost either before or after surgery, mostly from anaesthetic difficulties. Ether was found to be best. Two other animals died, one and two weeks following surgery; twenty-nine animals were left in which the experiments were completed.

The right lower limb was prepared with a depilatory, cleaned with ether, and painted with tincture of merthiolate. Sterile drapes exposed the right knee region and sterile operating room technique was used. A parapatellar incision was made, the knee joint capsule was incised, and patella was dislocated laterally in order to expose the distal portion of the femur, including the epiphyseal cartilage and the metaphysis.

In one group of rabbits (Group I), a hole was drilled across the center of the epiphyseal plate, the drill being started in the intercondylar area and being stopped after it had penetrated the metaphysis of the femur. A one-eighth of an inch drill was used. This is about one-half the diameter of the shaft of the bone and roughly equivalent to a hole one-half of an inch in diameter in the epiphysis of a child ten years old. To lessen the likelihood of bone forming in this drill hole and retarding growth, a small piece of gelfoam was rolled up and was placed in the drill hole. It has been shown by Reynolds and Ford that gelfoam retards the formation of bone. The wound was then closed in layers with interrupted fine silk.

In another group of rabbits (Group II), an identical procedure was carried out, except that, in addition to passing a drill across the epiphyseal plate, a small curette was placed in the drill hole and the remaining central portion of the epiphyseal cartilage was curetted until only the cortical portion remained. Again, gelfoam was placed in the defect and was cut off flush with the joint surface; the dislocation of the patella was reduced, and the wound was closed.

In the third series of animals (Group III), the distal portion of the femur was exposed a little more extensively and the epiphyseal area was exposed in its entire circumference. With a small short curette, the peripheral portion of the epiphyseal plate with its overlying perichondrium and synovial membrane was removed entirely around the bone. The wound was then closed in the same manner.

Surprisingly, there was no evidence of infection postoperatively or at sacrifice in any of the animals.

The animals were sacrificed at intervals varying from ten to sixteen weeks. The femur and the tibia on each side were dissected out, were examined grossly, and were preserved in formalin. They were then x-rayed and measured; microscopic sections were

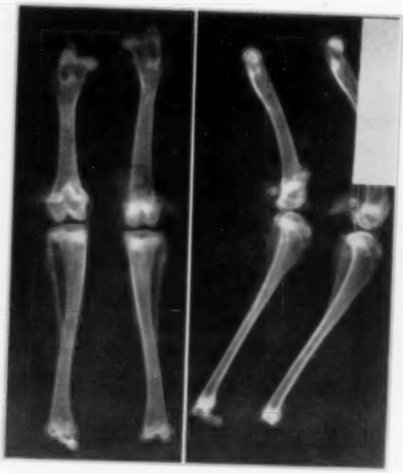


Fig. 1

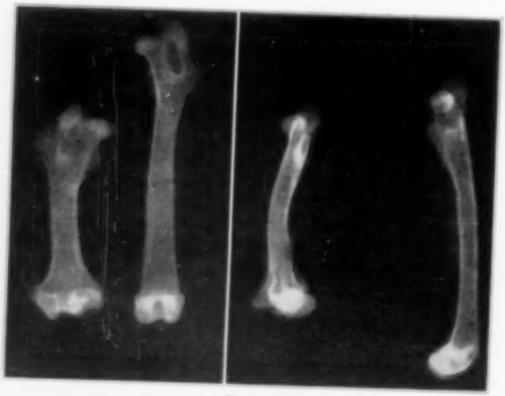


Fig. 2

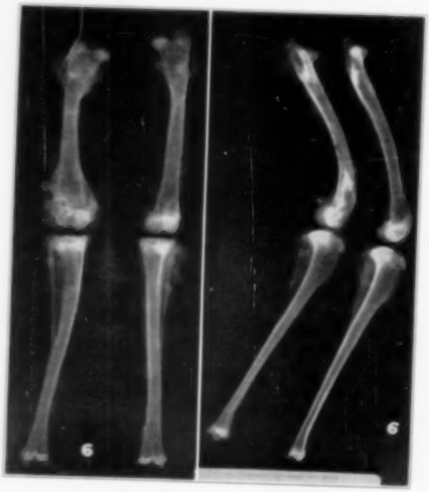


Fig. 3

Fig. 1: Roentgenograms of the legs of a rabbit in which the right femoral epiphysis had been damaged by drilling across the center of the epiphysis ten weeks previously.

Fig. 2: Roentgenograms of the femora of a rabbit in which the central portion of the distal femoral epiphysis of the bone on the left had been curetted sixteen weeks previously. There was 2.8 centimeters of shortening.

Fig. 3: Roentgenograms of the legs of a rabbit in which the periphery of the epiphyseal line had been curetted thirteen weeks previously. There was shortening of 0.7 centimeter. An exostosis is seen in the anteroposterior view on the metaphysis of the femur operated upon.

prepared of the distal portion of the femur on each side, the right femur being the one operated upon and the left being the control.

## ROENTGENOGRAPHIC EXAMINATION

### *Group* I (*eleven rabbits*)

In these animals the center of the epiphysis was drilled. No marked deformities were present. Several femora showed broadening of the distal portion and sclerosis and irregularity of the epiphyseal line. One showed moderate anterior bowing. In the others, except for slight shortening, there was no difference from the control bones. Several exostoses in the metaphyseal area were seen (Fig. 1).

### *Group* II (*eight rabbits*)

In these drilling and the curettement of the center were done. Marked shortening with broadening and distortion of the distal portion of the entire femur was present in most femora. Not much angulatory deformity was present. The size and shape of several femora simulated those of a chondrodysplastic dwarf (Fig. 2).

### *Group* III (*ten rabbits*)

Curettement of the periphery of the epiphysis was done. Moderate shortening and

TABLE I

DRILLING OF CENTER OF EPIPHYSIS (GROUP I)

| Animal No. | Time from Surgery to Sacrifice (*Weeks*) | Length of Femur Operated on (*Centimeters*) | Length of Control Femur (*Centimeters*) | Difference | Length of Tibia Operated Side (*Centimeters*) | Length of Tibia Control Side (*Centimeters*) | Difference |
|---|---|---|---|---|---|---|---|
| 21 | 11 | 8.4 | 9.3 | 0.9 | 9.8 | 9.8 | 0 |
| 22 | 11 | 9.8 | 10.0 | 0.2 | 10.4 | 10.4 | 0 |
| 23 | 11 | 8.6 | 9.6 | 1.0 | 10.2 | 10.1 | +0.1 |
| 25 | 10 | 8.9 | 9.2 | 0.3 | 9.4 | 9.3 | +0.1 |
| 26 | 10 | 8.4 | 9.3 | 0.9 | 9.6 | 9.6 | 0 |
| 27 | 10 | 8.2 | 8.5 | 0.3 | 9.2 | 9.2 | 0 |
| 28 | 10 | 8.5 | 9.2 | 0.7 | 9.7 | 9.8 | −0.1 |
| 29 | 10 | 8.9 | 9.4 | 0.5 | 10.1 | 10.0 | +0.1 |
| 30 | 10 | 9.2 | 9.3 | 0.1 | 10.0 | 10.1 | −0.1 |
| 31 | 10 | 8.1 | 9.2 | 1.1 | 9.8 | 9.8 | 0 |
| Average | 10.3 | 8.7 | 9.3 | 0.6 (6.4 per cent) | | | |

broadening of the distal portion of the femur was present. Angulatory deformity, especially anteriorly, was present frequently. Considerable subperiosteal bone had apparently been formed, and several exostoses were noted above the epiphyses (Fig. 3).

Five of the eleven femora operated upon showed varying degrees of varus or valgus deformity. In all control femora in all three groups, the epiphyseal line was still present.

## GROSS EXAMINATION AND MEASUREMENT

### *Group* I. (*Drilling of the Center*)

All of the femora operated upon showed some scarring in the knee joint and most showed degenerative arthritic changes. Several had grooves or ridges marking the track of the patella. The site of the drill hole was usually visible, having healed over with fibrous tissue or fibrocartilage.

The eleven animals in this group had been sacrificed ten and eleven weeks after surgery (10.3 weeks average). The control femora measured an average of 9.3 centimeters in length. The experimental ones averaged 8.7 centimeters. Thus, there was an average difference of 0.6 centimeter, with the maximum being 1.1 centimeters, and the minimum, 0.1 centimeter. Thus the average shortening was 6.4 per cent of the length of the normal femur at the time of sacrifice.

### *Group* II. (*Drilling with Curettement*)

Deformities were more marked than those in Group I. Definite scarring with degenerative changes were present in all knee joints. In several, the patella had worn grooves in the distal portion of the femur.

The eight femora in this group showed an average length of 9.5 centimeters on the control side and 7.4 centimeters on the experimental side. There was, thus, an average shortening of 2.1 centimeters or 22.1 per cent with a maximum of 2.8 centimeters and a minimum of 1.6 centimeters. The average time from surgery to sacrifice in this group was sixteen weeks and the average shortening was 22.1 per cent.

### *Group* III. (*Curettement of Periphery*)

Most of the ten specimens showed considerable bone deformity. There was scarring about the joints, and degenerative arthritic changes were present in nearly all of them. Two femora showed an exostosis. Three had a groove anteriorly worn by the patella.

TABLE II

DRILLING WITH CURETTEMENT OF CENTER OF EPIPHYSIS (GROUP II)

| Animal No. | Duration of Experiment (*Weeks*) | Length of Femur Operated On (*Centimeters*) | Length of Control Femur (*Centimeters*) | Difference | Length of Tibia Operated Side (*Centimeters*) | Length of Tibia Control Side (*Centimeters*) | Difference |
|---|---|---|---|---|---|---|---|
| 7 | 14 | 7.2 | 9.4 | 2.2 | 10.2 | 10.1 | +0.1 |
| 14 | 16 | 7.0 | 9.8 | 2.9 | (not measured) | | |
| 15 | 16 | 7.3 | 9.2 | 1.9 | 10.1 | 10.0 | +0.1 |
| 16 | 16 | 7.6 | 9.3 | 1.7 | 9.9 | 9.8 | +0.1 |
| 17 | 16 | 7.3 | (operated) | | (fractured) | | |
| 18 | 16 | 7.6 | 9.3 | 1.7 | 10.1 | 10.0 | 0 |
| 19 | 16 | 7.3 | 9.9 | 2.6 | 10.9 | 10.8 | +0.1 |
| 20 | 16 | 7.9 | 9.5 | 1.6 | 10.1 | 10.0 | +0.1 |
| Average | 16 | 7.4 | 9.5 | 2.1 (22.1 per cent) | | | |

By measurement there was an average length of 9.6 centimeters in the control femora, and 8.2 centimeters in the experimental femora; or an average shortening of 1.4 centimeters (14.5 per cent), with a maximum of 2.2 centimeters and a minimum of 1.0 centimeter. The average time from surgery to sacrifice was fourteen weeks.

In all three groups, the tibiae were examined and measured. In twenty-five there was a difference in length of 0.1 centimeter or less. In Group III the tibiae of four rabbits were longer by 0.2, 0.2, 0.3, and 0.4 centimeter. In these limbs the differences in femoral length had been 1.4, 1.6, 1.7, and 2.0 centimeters. There was thus no conclusive evidence

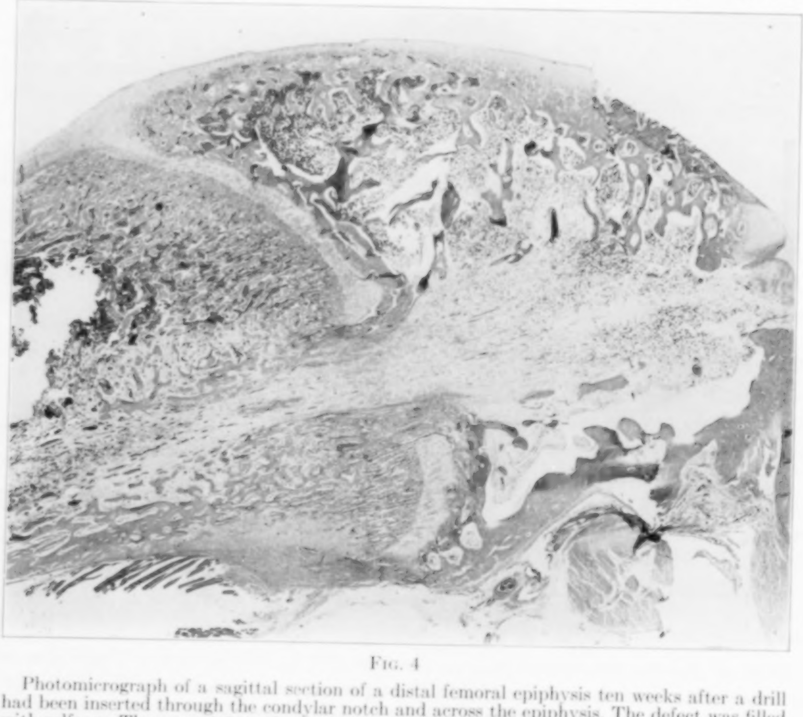


FIG. 4

Photomicrograph of a sagittal section of a distal femoral epiphysis ten weeks after a drill had been inserted through the condylar notch and across the epiphysis. The defect was filled with gelfoam. There was 1.0 centimeter of shortening of this extremity. (× 5.)

TABLE III

CURETTEMENT OF PERIPHERY (GROUP III)

| Animal No. | Duration of Experiment (*Weeks*) | Length of Femur Operated On (*Centimeters*) | Length of Control Femur (*Centimeters*) | Difference | Length of Tibia Operated Side (*Centimeters*) | Length of Tibia Control Side (*Centimeters*) | Difference |
|---|---|---|---|---|---|---|---|
| 3 | 16 | 8.3 | 9.3 | 1.0 | 10.1 | 10.1 | 0 |
| 4 | 15 | 8.2 | 9.9 | 1.7 | 10.7 | 10.4 | +0.3 |
| 5 | 15 | 8.9 | 9.5 | 1.4 | 10.2 | 10.0 | +0.2 |
| 6 | 13 | 8.6 | 9.3 | 0.7 | 10.2 | 10.0 | +0.2 |
| 8 | 14 | 7.9 | 9.9 | 2.0 | 11.1 | 10.7 | +0.4 |
| 9 | 14 | 8.9 | 10.5 | 1.6 | 11.4 | 11.2 | +0.2 |
| 10 | 13 | 7.9 | 9.6 | 1.7 | 10.3 | 10.2 | +0.1 |
| 11 | 13 | 8.2 | 9.7 | 1.5 | 10.4 | 10.3 | +0.1 |
| 12 | 14 | 7.7 | 9.2 | 1.5 | 9.9 | 9.9 | 0 |
| 13 | 14 | 8.6 | 9.7 | 1.1 | 10.7 | 10.7 | 0 |
| Average | 14 | 8.2 | 9.6 | 1.4 (14.5 per cent) | | | |

that nature will cause a concommitant overgrowth of another bone in a limb when one bone has growth interference, as the slight excess growth of the tibia may have been caused by the operative trauma.

## MICROSCOPIC FINDINGS

### *Group* I. (*Drilling Only*)

In nine of the eleven specimens the sections crossed the epiphysis at the site of the

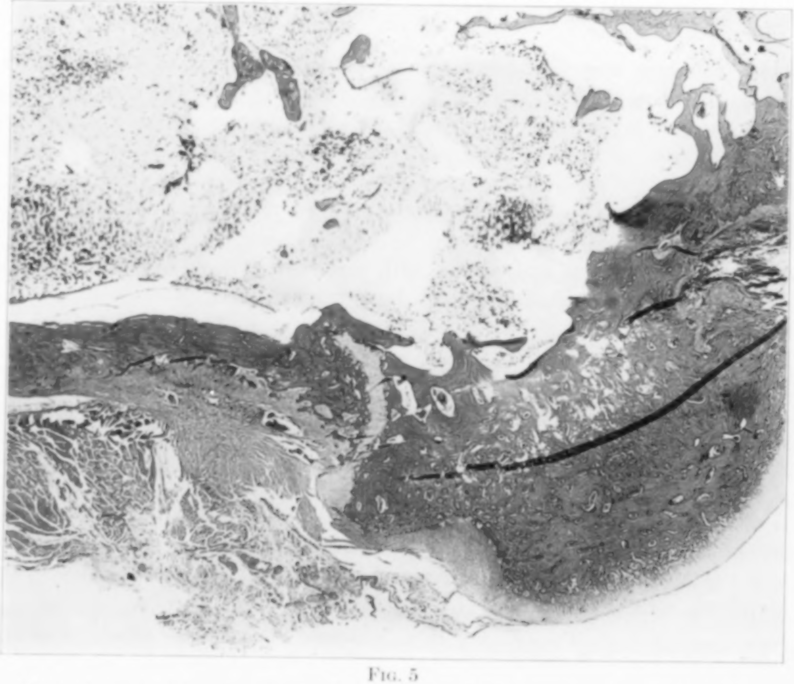


FIG. 5

Photomicrograph of sagittal section of the femur in which the entire center of the epiphysis had been curetted sixteen weeks previously. A remnant of the epiphyseal plate was bridged by bone on the marrow side and was apparently not functioning. This femur, shown in Fig. 2, had 2.8 centimeters of shortening. (× 7.)

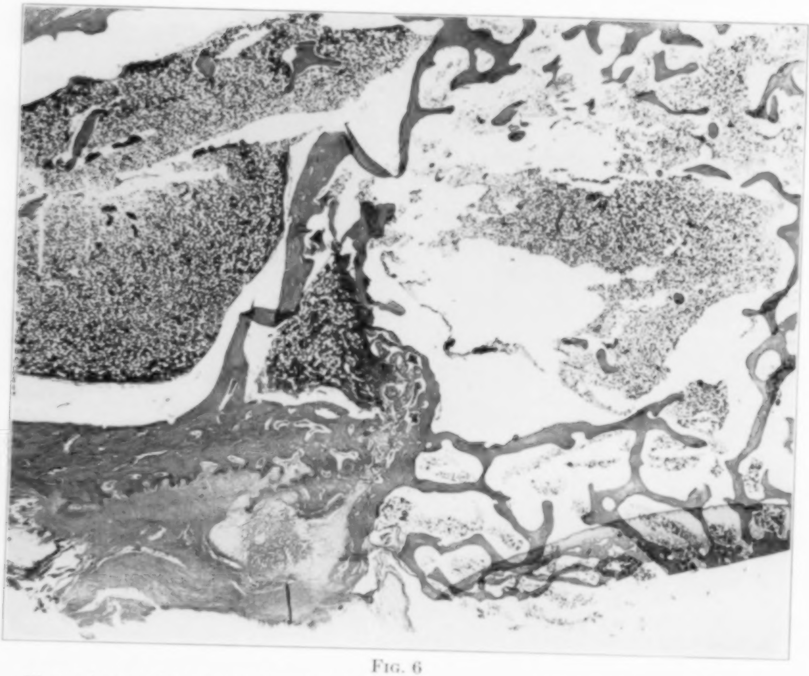


FIG. 6

Photomicrograph of an epiphyseal plate after curettement of the periphery. A thin band of bone replaced the epiphyseal line. Some cartilage remained posteriorly. (× 7.)

drill hole. The hole was filled with fibrous connective tissue in two instances, and trabeculae of bone were growing across it in the remaining nine. The epiphyseal cartilage away from the hole in its center was usually normal in appearance, but the epiphysis was fused by bone around the periphery of the drill hole. When epiphyseal cartilage was present, a thin plate of cortical bone was present on the epiphyseal side. In all sections, control and experimental, when epiphyseal cartilage was found, there was found also a difference in the bone and marrow structure of the epiphysis and metaphysis. In the epiphysis, the trabeculae of bone were a little denser than those in the metaphysis, and the intertrabecular spaces were filled with fatty marrow while those in the metaphyseal area were filled with hematopoietic cells (Fig. 4).

### *Group* II. (*Drilling and Curetting of the Center of the Epiphysis*)

In these sections (Fig. 5), the large defect in the epiphysis was seen microscopically. There was disorganization and distortion of this portion of the bone structure in each. In one, a cavity appeared to be filled with remnant gelfoam. In others it was filled with fibrous connective tissue with trabeculae of bone. In two specimens, there were displaced islands of epiphyseal cartilage up in the metaphyseal area. Several specimens showed remnants of the epiphyseal plate in the cortical region but this was surrounded by sclerotic bone and appeared not to be functioning, and the epiphysis was fused to the metaphysis by a peripheral zone of bone.

### *Group* III. (*Curettement of Periphery*)

In five of the ten specimens, no remnant epiphyseal cartilage was found. When the epiphyseal cartilage was absent, there was found a thin cortical plate of bone extending across the femur in the site of the previous epiphyseal cartilage plate and separating the

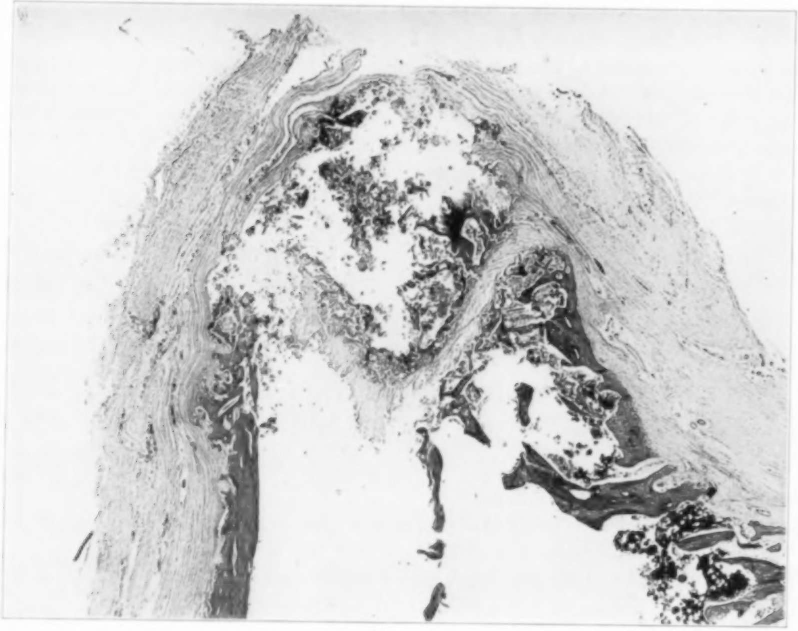


FIG. 7

Photomicrograph of exostosis which developed after the periphery of the epiphysis had been curetted thirteen weeks earlier. The exostosis is seen in Fig. 3. The band of fibrous tissue across the exostosis had some cartilage cells in it and it is believed that the exostosis resulted from some displaced epiphyseal cells (× 12).

fatty marrow of the epiphysis from the hematopoietic marrow of the metaphysis (Fig. 6).

One specimen showed an area near the cortex and above the epiphysis which contained fibrous tissue and simulated the fibrous metaphyseal defects of bone.

In five animals remnant patches of lines of the original epiphyseal plate were found. Two specimens demonstrated exostoses and these were found to have a patch of epiphyseal cartilage cells still arranged in columns which suggested the exostosis had resulted from growth of a displaced fragment of epiphyseal cartilage removed at the time of the original curettement (Fig. 7).

## DISCUSSION

The three types of trauma to the distal femoral epiphysis carried out in this experiment have consistently produced varying amounts of growth interference and, in many instances, gross deformities of the bone. The authors felt, at the outset, that the peripheral portion of the epiphyses played a more active role in growth than did the central portion and were surprised to find that animals in Group II in which the central portion of the epiphysis was destroyed showed more interference with growth.

The discrepancy in duration of the experiments is admitted but as the results are given in percentage of the length of the normal femur at the time of sacrifice, we think that this discrepancy does not alter our conclusions. Although epiphyseal cartilage was still present in all the control femora on section and by x-ray, the rabbits themselves had reached adult size. The average length of control femora in Groups I, II and III were about the same (9.3, 9.2, and 9.6 centimeters, respectively), while the duration of the experiments was an average 10.3, sixteen, and fourteen weeks, respectively.

In the experimental femora in Groups II and III no additional growth could be expected since epiphyseal cartilage was either not present or there were only a few remnants which were badly distorted and the epiphysis was fused to the metaphysis. It is believed that curettement of the periphery results in premature closure of the epiphyses by eventual healing of the defect in the cortical bone of the femur, and that the remaining central epiphyseal cartilage is simply absorbed when it can no longer contribute to growth. A thin cortical plate of bone remains, however, in its place.

At first the authors thought that some of the animals which showed marked anterior angulation deformity had had epiphyseal separation, but study of sections indicates that this was probably the result of arrest of one portion of the epiphysis sooner than another. After extensive damage either to the periphery or the central portion of the epiphyseal cartilage plate the entire plate tends to fuse, with bony union of the metaphysis and epiphysis.

## CONCLUSIONS

1. Three types of experimental trauma to an epiphysis were carried out in rabbits.
2. A small part of the central portion of the epiphysis can be damaged and result in only mild or moderate growth interference.
3. When the entire peripheral portion of an epiphysis is damaged, marked growth limitation and deformity can be expected.
4. Extensive damage to or destruction of the central area of an epiphysis will result in a most marked interference in growth, but with less deformity.
5. It is noted that an osteocartilaginous exostosis may result when a patch of epiphyseal cartilage cells is displaced outside the shaft of the bone.
6. Extreme care to avoid damage to an epiphysis should be taken when bone surgery is necessary in children.

## REFERENCES

1. Gatewood, and Mullen, B. P.: Experimental Observations in the Growth of Long Bones. Arch. Surg., **15:** 215–230, 1927.
2. Haas, S. L.: The Relation of the Blood Supply to the Longitudinal Growth of Bone. Am. J. Orthop. Surg., **15:** 157–171, March 1917; **15:** 305–316, Apr. 1917.
3. Haas, S. L.: Restriction of Bone Growth by Pins Through the Epiphyseal Cartilaginous Plate. J. Bone and Joint Surg., **32-A:** 338–343, Apr. 1950.
4. Hatt, R. N.: The Central Bone Graft in Joint Arthrodesis. J. Bone and Joint Surg., **22:** 393–402, Apr. 1940.
5. Hellstadius, Arvid: An Investigation by Experiments on Animals of the Rôle Played by the Epiphyseal Cartilage in Longitudinal Growth. Acta Chir. Scandinavica, **95:** 156–166, 1947.
6. Hellstadius, Arvid: On the Importance of Epiphyseal Cartilage to Growth in Length. Acta Orthop. Scandinavica, **20:** 84–88, 1950.
7. Lacroix, Pierre. La rôle du cartilage de conjugaison dans l'allongement des os. Acta Orthop. Scandinavica, **18:** 373–376, 1949.
8. Phemister, D. B.: Operative Arrestment of Longitudinal Growth in the Treatment of Deformities. J. Bone and Joint Surg., **15:** 1–15, Jan. 1933.
9. Reynolds, F. C., and Ford, L. T.: Experimental Use of Gelfoam to Fill Defects in Bone. J. Bone and Joint Surg., **35-A:** 980–982, Oct. 1953.
10. Speed, J. S., and Macey, H. B.: Fractures of the Humeral Condyles in Children. J. Bone and Joint Surg., **15:** 903–919, Oct. 1933.

# VERTEBRAL-BODY BIOPSY *

BY FREDERICK S. CRAIG, M.D., NEW YORK, N. Y.

*From the New York Orthopaedic Hospital at the Columbia-Presbyterian Medical Center, New York City*

Despite improved techniques of physical, laboratory, and x-ray diagnosis, there still remain cases in which actual pathological material must be studied before the nature of the disease can be determined. Many times a suitable specimen of pathological material can be obtained only from a vertebral body. Although approaches to the vertebral bodies by surgical exposure and needle biopsy have been known for many years,[1,2,3,4,5,6,7,8] the surgeon has often been deterred from using them because of the hazard of injury to surrounding vital structures and because of the possibility of deep bleeding which is difficult to control. Furthermore, when he has used them, they have not always produced adequate amounts of material for study.

In 1928, in a case reported by Duncan and Ferguson, von Lackum used a transpedicle approach to curette a giant-cell tumor in the fourth lumbar vertebral body. Since previous attempts to treat such tumors had often ended in collapse of the vertebral body and in cord pressure, a spine fusion was performed. Compere, in 1932, reported an approach for excision of hemivertebrae. In 1935, Robertson and Ball reported a method of needle biopsy that had been in use since 1932. They noted that it is difficult to obtain cartilaginous or fibrous material by this method and warned of the danger of injury to the cord. In 1948, Valls and Ottolenghi presented an ingenious device for making an accurate needle approach to the vertebral bodies at a measured angle of thirty-five degrees. They described techniques for making approaches at all spinal levels but advised against making an approach above the ninth thoracic vertebra because of the possibility of injury to the azygos and hemiazygos systems. They stated that the vertebral bodies cannot be approached surgically. In 1949, Michele and Krueger presented a study of various surgical approaches to the vertebral bodies. They also described a new trephine, for obtaining biopsy material, and illustrated the proper methods of using the instrument. Since 1949, there have been additional articles which have demonstrated the value and use of needle biopsy[3,5,7].

At this Clinic open biopsy has been employed infrequently. The first instance of its use, an approach to the ninth thoracic vertebra by subperiosteal dissection along the pedicle, was the most successful. Subsequent cases demonstrated the inherent weaknesses and dangers of this technique, and the results in two cases caused its abandonment. In a patient with osteomyelitis, a biopsy of the eighth thoracic vertebra resulted in wound infection, collapse of the segment, shearing of the cord, and death. In a patient with a metastatic carcinoma of an unknown primary site, it was very difficult to make an accurate approach because the transverse process and the pedicle, both very valuable as landmarks, had been destroyed by metastatic growth. Since easier techniques are available, morbidity due to open biopsy is rarely justified.

At times, pathological material can be obtained by any type of long needle. In the past, we have secured adequate material for diagnosis from the eleventh thoracic vertebra with a lumbar puncture needle. We have had failures as well as successes in our attempts to secure biopsy material by such needles, however, and so a set of instruments was designed which we hoped would result in a high percentage of successful biopsies in sclerotic or softened bone, in discs, or in fibrous tissues.

The set centers around a cannula (Fig. 1-A, *A*). This cannula, 11.5 centimeters in

---

* Based on an Exhibit at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Los Angeles, California, January 29, 1955, to February 3, 1955.

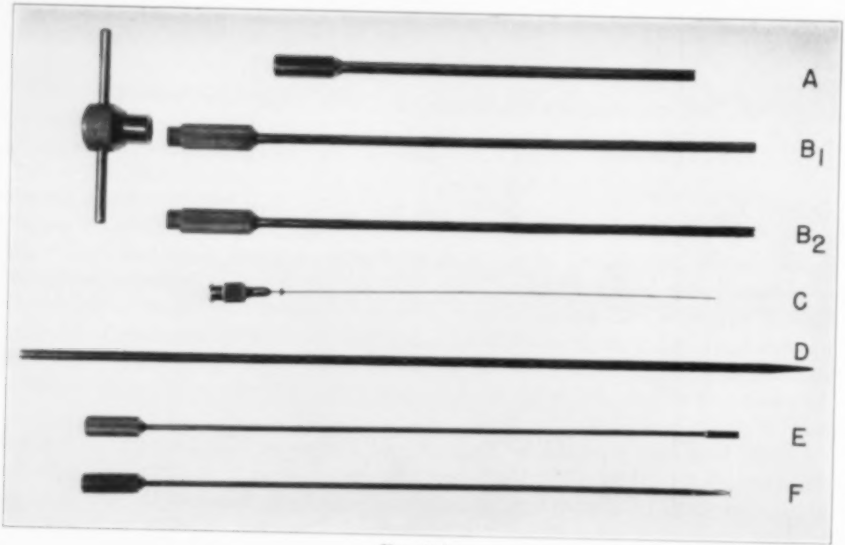


Fig. 1-A

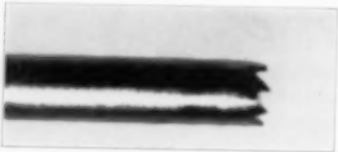


Fig. 1-B

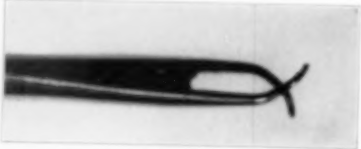


Fig. 1-C

length, is long enough to reach a lumbar vertebral body in an obese patient but is not long enough to penetrate the aorta in a thin subject. The set contains two cutters (Fig. 1-A, $B_1B_2$) and the biopsy is done by one of these cutters inserted within the protecting wall of the cannula. These cutters can project only 2.5 centimeters beyond the end of the cannula; and they have an inside diameter of 3.5 millimeters. This diameter was selected as the minimum necessary to secure a section unspoiled by surface artifacts. The cutters, one toothed (Fig. 1-B), one knife-edged, have hubs to which can be fitted either a wrench for removing sclerotic bone or a syringe for aspirating pus or soft tissue. Additional parts of the set include a 22-gauge exploring and infiltration needle with a Luerlok hub (Fig. 1-A, *C*) and a trocar with a semi-blunt point (Fig. 1-A, *D*). The trocar is used to push aside nerve trunks, vessels, and other tissues between the surface and the centrum selected; it also serves as a guide for the cannula. Also in the set is a blunt-pointed stylet (Fig. 1-A, *E*) which fits into the lumen of the cutter and can be used to palpate tissues ahead of this cutter and to determine the length of the section already within it. The final and one of the most important adjuncts is a sharp-toothed worm (Fig. 1-A, *F*, and 1-C). The worm insures that the cut section is removed as the cutter is withdrawn, and it is this device which obviates the objection of Robertson and Ball that soft tissue and cartilage cannot be obtained easily by these instruments.

## TECHNIQUE

When possible, the skin of the patient's back is prepared with soap the night before the procedure. Thirty minutes before the procedure, if there are no contra-indications, he is given sodium phenobarbitol and an opiate. He is placed prone on the x-ray table with pillows under the head and the tibiae for comfort, and the back is prepared. With

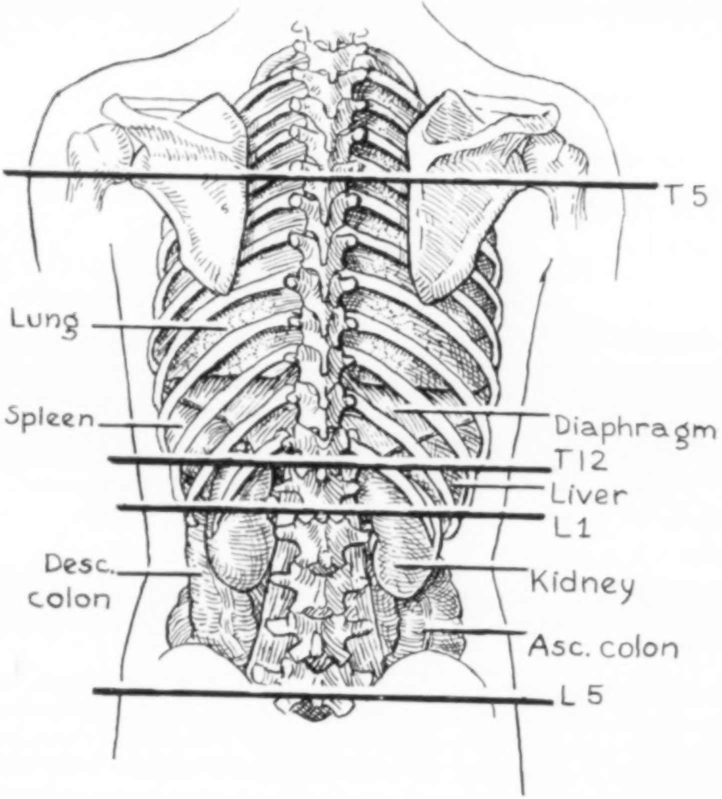


FIG. 2

This diagram shows the position of the large internal organs in relation to the spine. The horizontal cross sections which follow show the proper position of the trocar in relation to the vital organs at the levels which are indicated by the black bands in this drawing.

the aid of an anteroposterior roentgenogram, the area on which the biopsy is to be performed is selected and the needle path is planned according to the necessity of bypassing a rib or a transverse process. In the thoracic region it is desirable to make the skin wheal medial to the angle of the rib so that the pleural cavity may be avoided. In the lumbar area, it is desirable to approach the body at right angles to its posterior third in order to avoid skidding; this is accomplished by puncturing the skin at a point seven to eight centimeters from the mid-line, the exact distance depending on the width of the bodies as seen by the roentgenogram. Once the path is planned, the 22-gauge needle is inserted at approximately 35 degrees to the perpendicular and advanced toward the spine, the fascial planes being infiltrated with 2 per cent novocaine as they are encountered. Any bone which is met before one-half of the infiltration needle has been inserted is a transverse process, an excellent landmark. The transverse process is bypassed either above or below, and the needle is further advanced. Usually radicular pain is next noted by the patient, at which point the syringe is removed from the needle and the lumen of the needle observed for one minute for the escape of cerebrospinal fluid. If no spinal fluid is seen, the needle is advanced another 0.5 centimeter to the bone, the periosteum is lightly infiltrated, and anteroposterior and lateral roentgenograms are made. From these films, the relationship of the needle to the desired point is determined, and the further

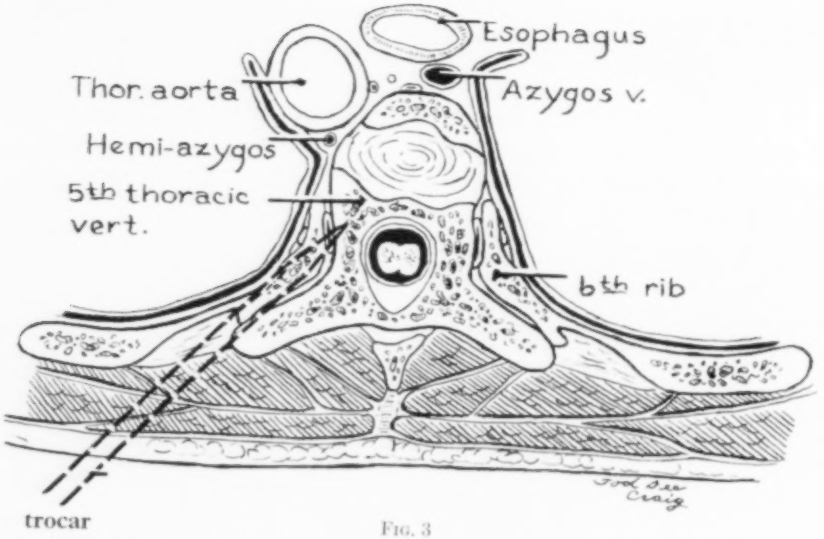

Esophagus
Thor. aorta
Azygos v.
Hemi-azygos
5th thoracic vert.
6th rib
trocar
Tod Dee Craig

FIG. 3

At the level of the sixth thoracic vertebra, the azygos and hemiazygos veins are well anterior to the centrum. The trocar should not be inserted until roentgenograms have been made which show that the angle of approach of the infiltration needle is correct. It is unnecessary to enter the pleural cavity.

route of the needle is planned. A stab wound through the skin and lumbodorsal fascia is then made with a Bard Parker No. 1 blade, and the trocar is passed. Usually more infiltration with novocaine is necessary. The position of the trocar is checked roentgenographically, and if this position is satisfactory, the trocar is held with its point firmly fixed against bone. The cannula is next passed over the trocar with a twisting motion until the end rests

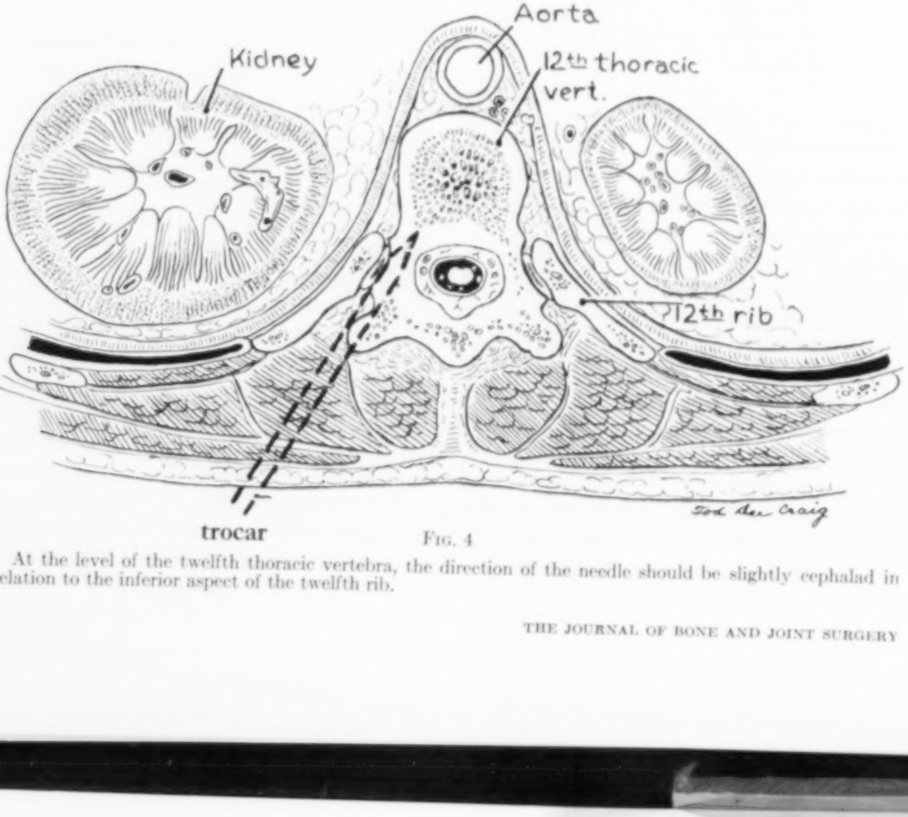

Aorta
Kidney
12th thoracic vert.
12th rib
trocar
Tod Dee Craig

FIG. 4

At the level of the twelfth thoracic vertebra, the direction of the needle should be slightly cephalad in relation to the inferior aspect of the twelfth rib.

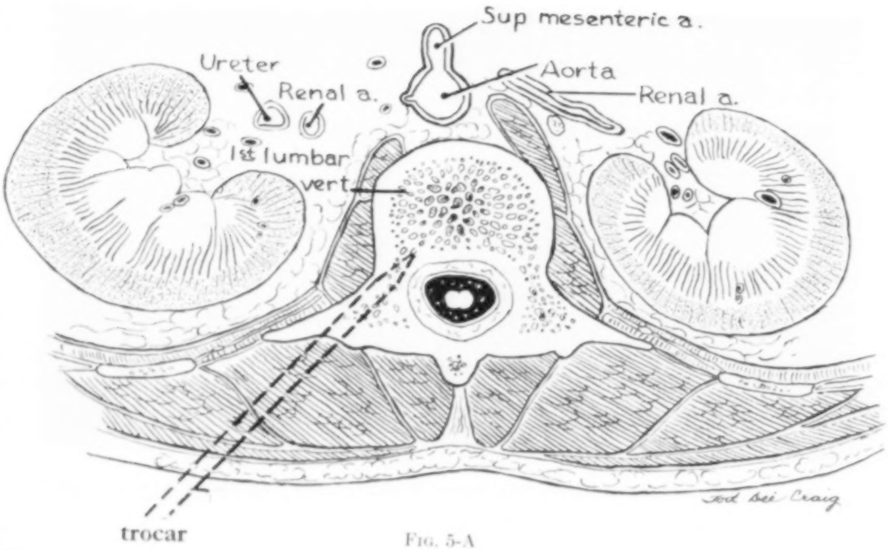

Sup mesenteric a.
Ureter
Renal a.
Aorta
Renal a.
1st lumbar vert.
Tod Dei Craig
trocar

Fig. 5-A

Figs. 5-A and 5-B: The first through the fifth lumbar vertebrae are more accessible and there is less danger to the patient if the approach at this level is made at right angles to the posterior third of the body. An adequate roentgenographic study should be made after each step.

against bone or annulus fibrosus. It is essential that one of the operator's hands constantly holds the cannula to prevent it from slipping or entering very soft bone. If necessary, 2 per cent novocaine can be injected through the cannula. One of the cutters, usually the toothed one, is placed in the cannula and is used like a cork borer to cut the bone. From

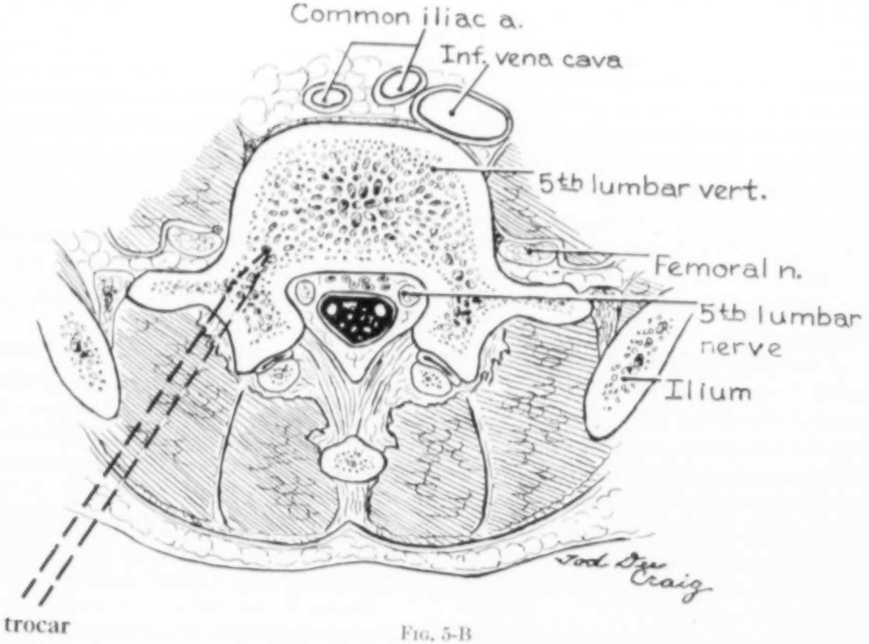

Common iliac a.
Inf. vena cava
5th lumbar vert.
Femoral n.
5th lumbar nerve
Ilium
Tod Dei Craig
trocar

Fig. 5-B

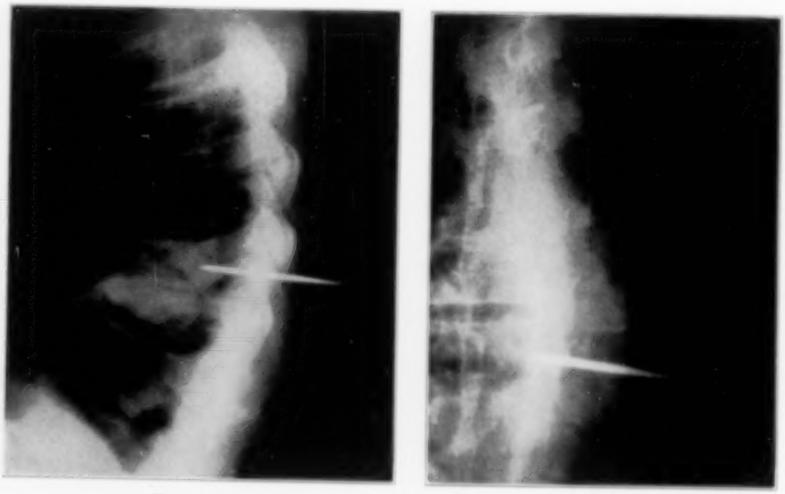


FIG. 6-A FIG. 6-B

Figs. 6-A and 6-B: Anteroposterior and lateral films showing the trocar inserted in the proper position for guiding the cannula.

time to time, the lumen of the cutter is palpated with the blunt stylet in order to determine the length of the core being obtained. The stylet is left in the cutter as the latter is withdrawn as an indicator that the core is also retained. It is often necessary to use the worm to ensure that the core actually is removed with the cutter. After the withdrawal of the cutter, the blunt stylet is used to express the core into a fixative solution. If the biopsy is done in the region of the thoracic spine, the inferior surface of a rib is followed to a point slightly below the articulation of this rib with the body to be biopsied. The pleural space is avoided by the entrance previously suggested.

## DISCUSSION

After many biopsies had been performed, the following general observations were made. In the presence of an abscess, it is sometimes impossible to obtain adequate local anaesthesia to allow penetration of the cavity wall because of the tension causing severe radicular pain. The area to be biopsied must be carefully selected; otherwise, the section taken may show only the reaction of bone to the disease without revealing the cause of the disease. Overlying reactive bone sometimes plugs the cutter, and in these cases it is necessary to withdraw the cutter, to expell this bone, and to return the cutter through the cannula for additional material. Except in cases of Paget's disease, sections taken from sclerotic vertebrae may show only aseptic necrosis. In these cases multiple marginal sections should be cut.

When material is being obtained from the disc space, from very soft bone, or from a tumor, it may be necessary to hold the tissue securely with the worm in order to operate the cutter efficiently. When disc material is being obtained, it may also be necessary to approach the space at an angle in order to "pin" the soft tissue against the bone. Excessive bleeding may be controlled by re-inserting the trocar into the cannula for a few minutes or by packing the wound with gelfoam.

Figures 2, 3, 4, and 5 show the proper position of the trocar in relation to the vital organs at various levels. The approach must be from the dorsolateral aspect of the body in order to avoid skidding on hard bone into the neural canal or forward into the region of the great vessels.

The five cases presented illustrate the value of the technique as an accessory diag-

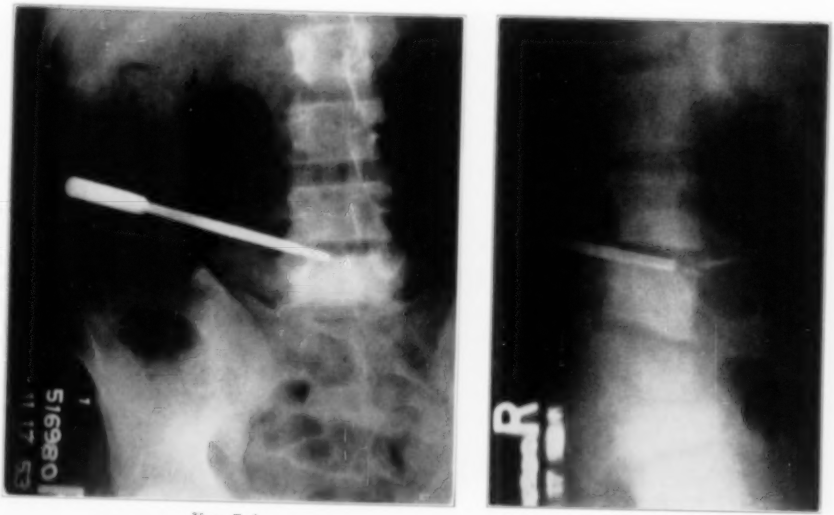


FIG. 7-A

FIG. 7-B

Figs. 7-A and 7-B: Anteroposterior and lateral films showing the cutter and cannula after they have been replaced in the hole from which disc and bone have just been removed.

nostic procedure which is direct in its approach, saving time and avoiding financial drain on the patient.

CASE 1. G. M., a white male, seventy-two years of age, was admitted on May 26, 1952, because of pain in the region of the tenth thoracic vertebra and because of a weight loss of thirty pounds in three months. He complained of nocturia and occasional cramping pains in the left upper quadrant of the abdomen. He had had a prostatectomy at another hospital three months prior to admission, and benign prostatic hypertrophy had been reported.

In the laboratory, the following results were obtained: the erythrocyte sedimentation rate was 126 millimeters per hour; the red blood count was 3.64 million per cubic millimeter and the white blood count, 11,600 per cubic millimeter; the urinalysis was negative; the acid phosphatase was 1.7 Gutman units per 100 milliliters and the alkaline phosphatase, 4.7 Bodansky units per 100 milliliters; the calcium was 4.3 milligrams per 100 milliliters and the phosphorus, 4.3 milligrams per 100 milliliters; the stool guiaic was negative.

Roentgenograms showed a narrowing of the fifth, sixth, and seventh intervertebral discs with hypertrophic spurs, marked osteoporosis of all bones, and marked compression of the ninth thoracic body. There was also some compression of the tenth thoracic body, and both these bodies were partially destroyed. In the anteroposterior view, the pedicle of the twelfth thoracic vertebra is less distinct on the left, suggesting the possibility of metastasis.

On May 31, 1952, a biopsy of the ninth thoracic vertebra was successfully performed. This biopsy revealed chronic granulomatous osteomyelitis associated with an old hemorrhage and fibrous scarring consistent with, but not diagnostic of, tuberculosis. Repeated sputum examinations and chest roentgenograms were negative for tuberculosis. On June 20, 1952, a spine fusion of the eighth thoracic vertebra through the eleventh thoracic vertebra was performed. The sedimentation rate on April 21, 1953, was 40 millimeters per hour, and in November 1953, it was 26 millimeters per hour. Recent roentgenograms show that the disease has probably been arrested. There is new-bone formation, but no increase in angulation, and the patient is now living an active life.

CASE 2. W. D., a colored male, fifty years old, was admitted in October 1952, with the complaint of low-back pain. This pain, which radiated to the low abdomen and which had been present for two months, was increased by activity and recumbency, but was slight when he was standing. The patient had lost twelve pounds. The laboratory findings were as follows: erythrocyte sedimentation rate, 44 millimeters per hour; hemoglobin, 14.9 grams per 100 milliliters; acid phosphatase, one Gutman unit per 100 milliliters; alkaline phosphatase, 5.9 Bodansky units per 100 milliliters; calcium, 11.2 milligrams per 100 milliliters; serum protein, 7.0 grams per 100 milliliters (albumin, 4.0 grams per 100 milliliters; globulin, 3.0 grams per 100 milliliters); non-protein nitrogen, 42 milligrams per 100 milliliters; the Mazzini test, the stool guiaic, the urinalysis, and the Bence-Jones protein were all negative.

The roentgenograms were read as "disclose areas of destruction involving the right superior lateral

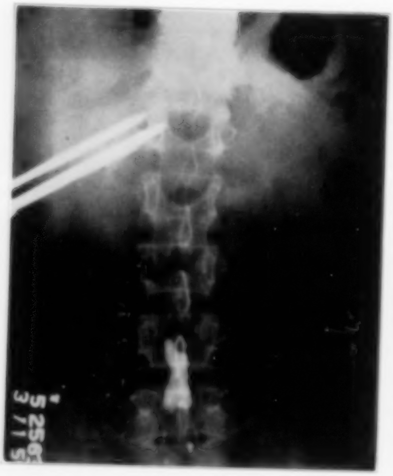


FIG. 8-A

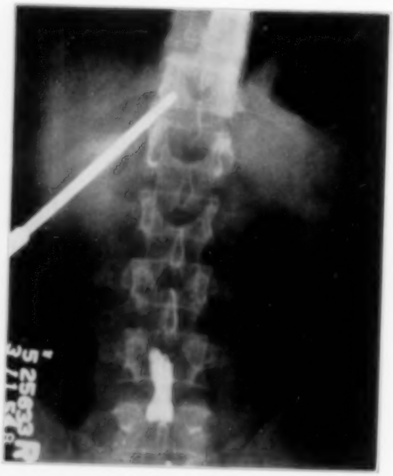


FIG. 8-B

Fig. 8-A: The cannula and cutter have been inserted into one of the pedicles of the first lumbar vertebra, and the trocar is properly placed for biopsy of the twelfth thoracic disc.

Fig. 8-B: This film demonstrates the proper approach for cutting a specimen from a disc and the adjacent bone.

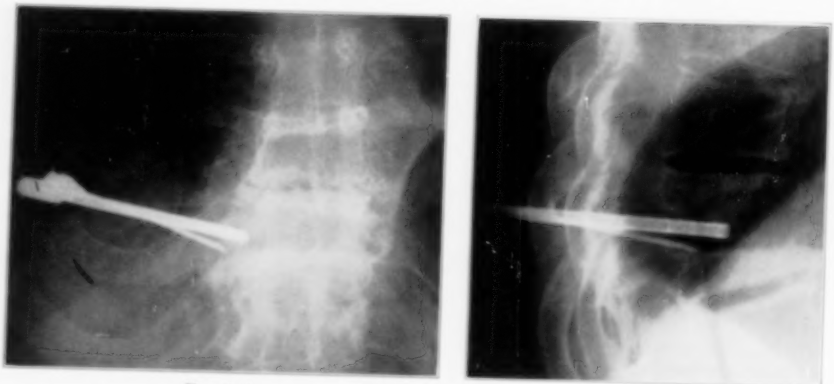


FIG. 9-A FIG. 9-B

Figs. 9-A and 9-B: Anteroposterior and lateral films showing insertion of the instruments for biopsy of the disc and adjacent bone. The diagnosis in this case was chronic osteomyelitis of the ninth and tenth thoracic vertebrae.

portion of the body of the fifth lumbar vertebra with a secondary radiolucency just medial to it and the right inferolateral portion of the fourth lumbar vertebra. Several areas of increased densities are seen within these areas of destruction suggesting sequestration. The entire body of the fifth lumbar vertebra and a portion of the body of the fourth lumbar vertebra are sclerotic."

Because of the sclerosis of the fifth lumbar vertebra, the first choice in diagnosis was osteomyelitis. A biopsy of the fourth lumbar intervertebral disc and of the fifth lumbar body was performed on November 18, 1952. Fluid was aspirated for culture from the disc space, and bone cores were obtained. The pathological diagnosis was osteomyelitis of the vertebral body. There was necrosis of the bone; hyaline cartilage and fibrocartilage were shown to be present in association with chronic and subacute inflammation. The cultures were negative, but the guinea pig died. On December 18, 1953, acid-fast bacteria were recovered from the Dubos culture. On December 28, 1953, a spine fusion from the third lumbar vertebra to the sacrum inclusive was performed; and on June 26, 1954, the patient was discharged from the hospital ambulatory and apparently with a solid fusion. It appeared that the disease had been arrested.

CASE 3. J. L., a white male, forty-one years old, was admitted after having undergone extensive studies at other hospitals for complaints of pain, boring, and burning in the region of the right upper quadrant

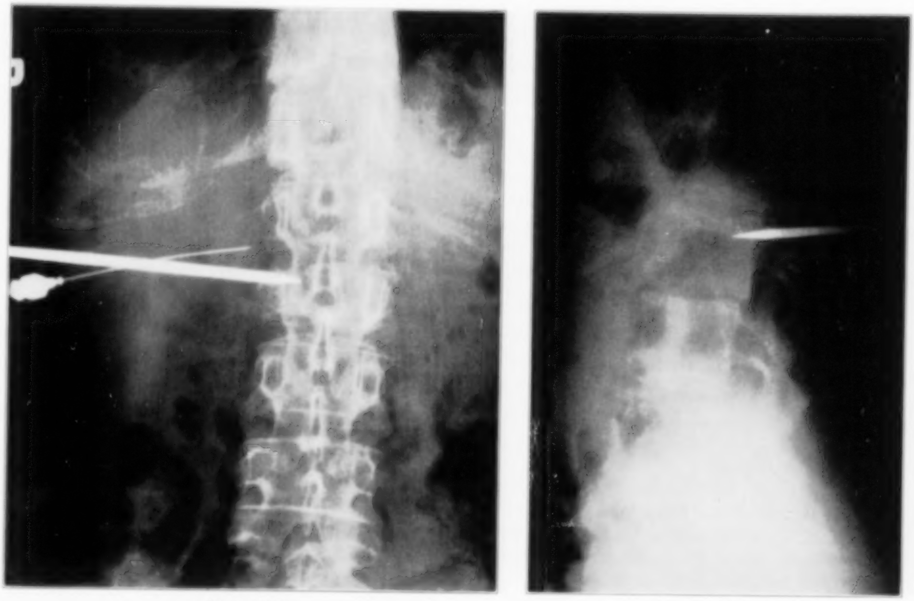


FIG. 10-A FIG. 10-B

Figs. 10-A and 10-B: Anteroposterior and lateral films showing the trocar correctly placed for biopsy of the second lumbar vertebra. The diagnosis in this case was adenocarcinoma of an unknown primary site.

and of the right kidney. During the two years he had suffered from these complaints, he had lost twenty-six pounds. A retrograde pyelogram, a myelogram, multiple roentgenograms of the spine, and a gastro-intestinal series were made; a lumbar puncture was performed; and the patient was given multiple physical examinations. The results of these tests and examinations were almost entirely negative; the only abnormality noted was a band of hyperaesthesia below the mid-line along the eleventh thoracic intercostal nerve. Laminagrams were done, and these showed that the right transverse process of the first lumbar vertebra was absent and that the twelfth thoracic disc was thin. Extensive chemical tests of the blood, including serum calcium, serum phosphorus, and proteins, showed normal values; and the blood count and the sedimentation rate were also normal.

A biopsy was done on the pedicle in the region of the absent transverse process, and an additional section was done on the nucleus pulposus of the twelfth thoracic disc. These sections revealed "normal fibrocartilage, bone, bone marrow, and connective tissue (from region of spine)." Bone disease was thus eliminated as the cause of the pain.

The patient was transferred to the neurosurgical service, and a laminectomy was performed on the eleventh thoracic segment revealing a thickened and adherent arachnoid. The cause of this localized condition was not determined. Anterior and posterior rhizotomies were performed on the eleventh and the twelfth thoracic segments. There were no pathological findings on examination of the leptomeninges.

In this case biopsy proved to be an easy method of eliminating a diagnosis of bone disease.

CASE 4. A. B., a white male, sixty-five years old, was admitted to the Francis Delafield Cancer Hospital on May 15, 1953, for further study and for terminal care. His chief complaint was that, following a fall on June 30, 1952, very severe low-back pain which was increased by movements had gradually developed. He had been admitted to the Hospital once previously for fever and hemoptysis. On that occasion a lobectomy of the left lung had been performed, the pathological findings being reported as pneumonitis and infarction. On his second admission for back pain, a number of therapeutic measures were applied including traction and roentgentherapy of the entire spine. These measures failed to bring relief. Roentgenograms revealed a markedly destructive lesion involving the ninth and tenth thoracic vertebrae which was interpreted as neoplastic or tuberculous.

When the usual thorough search for a primary tumor produced only negative results, a biopsy was performed on the ninth thoracic disc (May 20, 1953). This biopsy revealed osteomyelitis of a non-specific inflammatory type. He was treated by bed rest, antibiotics, and a Taylor brace; and on September 24, 1953, he was discharged to a convalescent home. The final diagnoses were acute nephritis (cured), chronic osteoarthritis of the spine, and chronic osteomyelitis of the ninth and tenth thoracic vertebrae.

The successful course of this case is in contrast to the disastrous course of the case diagnosed by open biopsy, a course which involved infection of the wound, vertebral-body collapse, cord pressure, and death.

Case 5. D. C., a white female, fifty-five years of age, was admitted on October 11, 1954, for low-back pain of eight months' duration. Roentgenograms showed diffuse osteoporosis of all bones and a collapse of the second lumbar vertebra. A physical examination was made, but no primary tumor could be found. The results of a gastro-intestinal series, an intravenous pyelogram, and various blood analyses were essentially negative. On November 9, 1954, a biopsy of the second lumbar vertebra was done, and the sections were interpreted as showing "metastatic carcinoma in bone, probably adenocarcinoma with the breast as the first consideration." Additional procedures have still failed to demonstrate a primary tumor.

In this case the biopsy resulted in a rapid diagnosis (of a destructive vertebral lesion), whereas no other procedure was of any value.

## REFERENCES

1. Compere, E. L.: Excision of Hemivertebrae for Correction of Congenital Scoliosis. Report of Two Cases. J. Bone and Joint Surg., **14:** 555–562, July 1932.
2. Duncan, G. A., and Ferguson, A. B.: Benign Giant-Cell Tumor of the Fourth Lumbar Vertebra. A Case Report. J. Bone and Joint Surg., **18:** 769–772, July 1936.
3. Frankel, C. A.: Aspiration Biopsy of the Spine. J. Bone and Joint Surg., **36-A:** 69–74, Jan. 1954.
4. Michele, A. A., and Krueger, F. J.: Surgical Approach to the Vertebral Body. J. Bone and Joint Surg., **31-A:** 873–878, Oct. 1949.
5. Ray, R. D.: Needle Biopsy of the Lumbar Vertebral Bodies. A Modification of the Valls Technique. J. Bone and Joint Surg., **35-A:** 760–762, July 1953.
6. Robertson, R. C., and Ball, R. P.: Destructive Spine Lesions. Diagnosis by Needle Biopsy. J. Bone and Joint Surg., **17:** 749–758, July 1935.
7. Sieffert, R. S., and Arkin, A. M.: Trephine Biopsy of Bone with Special Reference to the Lumbar Vertebral Bodies. J. Bone and Joint Surg., **31-A:** 146–149, Jan. 1949.
8. Valls, José; Ottolenghi, C. E.; and Schajowicz, Fritz: Aspiration Biopsy in Diagnosis of Lesions of Vertebral Bodies. J. Am. Med. Assn., **136:** 376–382, 1948.

# IMMUNOLOGICAL FACTORS IN HOMOGENOUS-BONE TRANSPLANTATION*†**

## I. Serological Studies

BY PAUL H. CURTISS, JR., M.D., AND CHARLES H. HERNDON, M.D., CLEVELAND, OHIO

*From the Department of Orthopaedic Surgery, Western Reserve University and University Hospitals, Cleveland*

The successful use of relatively small amounts of homogenous preserved bone has been repeatedly demonstrated both experimentally and clinically. The use of massive homogenous-bone grafts, with rare reported exceptions, has not met with the same success. In previously reported experiments on whole knee-joint transplants in dogs by one of the authors and a colleague [9], marked, consistent, gross and microscopic differences were noted in the homogenous transplants as compared with the autogenous joints. The former showed no retention of living cells, slow osteogenesis, and ultimate severe degenerative changes similar to those seen in avascular necrosis.

The work reported here was done in an attempt to determine if these differences in the behavior of transplanted autogenous and homogenous whole joints could be explained on the basis of an immunological response in the animal to homogenous whole bone acting as an antigen. It has been reported [9] as a clinical observation in the literature dealing with bone transplantation that the incompatibility of blood types between the donor and recipient has no apparent bearing on the success or failure of the graft. However, the authors have been unable to find any experimental work that would prove or disprove this assumption in regard to bone transplantation. The presence of the A, B, or A and B group-specific substance as a source of potential incompatibility was an obvious starting point for experimental observations on the possible effects of antigens of whole bone grafts, as bone transplants invariably contain varying amounts of blood. There is the additional possibility that bone tissue *per se* contains the A, B, or A and B group factors that are wide-spread in the other tissues of persons of those types.

The experiments by Young and his co-workers [7,17] on the determination of "blood groups" in dogs suggested that the dog is a potentially suitable research animal. They have described five "types" of dog red blood cells that were antigenically distinct. The most potent of these was the "canine A factor" which was able to produce high-titer "anti-A" antibodies capable of hemolysing "A-positive" red cells rapidly, both *in vivo* and *in vitro*. Anti-A serum was used to type and classify dogs into A-positive and A-negative groups. The demonstrated ability of the A antigen to produce a potent anti-A antibody was the basic research tool used in the serological experiments reported here and in the histological experiments to be reported at a later date.

### SEROLOGICAL EXPERIMENTS

### *A. Dog Bone in Rabbits*

*Problem:* Will the introduction of fresh heterogenous bone into a rabbit from a dog whose red blood cells contain the canine A factor result in the production of a type-specific antibody in the host animal against the canine A factor in the red blood cells of the donor?

---

* Supported in part by a grant from the United States Public Health Service and in part by the Cleveland Chapter of the Arthritis and Rheumatism Foundation.

† Presented in part at a conference on The Relation of Immunology to Tissue Homotransplantation of The New York Academy of Sciences, Feb. 12–13, 1954, and reported in part in the *Annals of The New York Academy of Sciences*, **59:** 434–442, Jan. 1955.

** Presented in part at the Annual Meeting of The American Academy of Orthopaedic Surgeons, January 31, 1955, Los Angeles, California.

*Experimental method:* Twelve rabbits were used, divided into three groups of four each. Under sterile conditions a pocket was made in a paravertebral muscle into which was placed one of the following preparations of bone from a dog whose red blood cells contained the canine A factor: whole fresh iliac bone (Group I), minced cancellous bone washed thoroughly by repeated shaking in solutions of sterile normal saline to remove as much blood as possible (Group II), cortical bone from which the marrow had been mechanically removed (Group III). The rabbits were bled from a vein or artery in the ear, and the serum was collected at regular intervals during a twelve-week period. The serum specimens were stored in the frozen state at −20 degrees centigrade until the end of the twelve-week period, when two-fold tube agglutination * and adsorption † tests were done.

Controls consisted of a group of five rabbits chosen at random and not operated upon, the serum from each of which was tested for agglutinins by the same method with the red blood cells of two random A-positive dogs (Table I). As was expected, cross agglutinations occurred frequently in low dilutions, but none occurred at a dilution higher than 1:4. In the agglutination tests done on the serum of the operated rabbits, a control of 0.1 milliliter of the test red-blood-cell suspension in 0.1 milliliter of normal saline was used.

It should be noted at this point that the designation of an A-positive or A-negative dog refers to a dog whose red blood cells do or do not contain the canine A substance. As shown by Young [17], the A, B, C, D, and E substances rarely occur alone, so that the above designations do not mean dogs whose red blood cells do or do not contain pure A substance only. The dog red blood cells used, and possibly the bone also, contained one or more of these other type-specific substances which can theoretically effect the development of the anti-B and anti-C isoantibodies and others. Young [17] has remarked on "the ease with which anti-C develops . . . (in C negative dogs) . . . after transfusions of C-positive cells . . . experience with the production of other canine isoantibodies has shown that, in general, they develop somewhat more slowly than anti-A and anti-C". Although realizing the desirability of the use of pure A-positive dogs (although Young did not find any in testing 138 random dogs), the authors had neither the variety of typing serum nor the number of available dogs to find such animals. It was particularly for this reason that adsorption tests were done, in an attempt to demonstrate the possibility that any antibody which developed in the rabbits was due to the canine A factor alone. Even here it must be pointed out that the demonstration of agglutinating antibody after adsorption with A-negative cells (concerning the antigenic composition of which it was only known that they did *not* contain the A factor) may be due to the presence of a factor in the A-positive red blood

---

* *Agglutination test:* The frozen specimens of rabbit serum were thawed, and then the complement was inactivated by heating at 56 degrees centigrade for thirty minutes. Two-fold dilutions with normal saline were made in small serology tubes, leaving 0.1 milliliter of each dilution in each tube. To each dilution was added 0.1 milliliter of a 3 per cent suspension of red blood cells (routine hematocrit determinations were done on all cell suspensions to insure uniformity). Each serum was tested against three cell suspensions: (1) a 3 per cent suspension of red blood cells from the donor dog in a solution of 50 per cent normal saline and 50 per cent autogenous serum, as suggested by Young [18]; (2) a 3 per cent suspension of red blood cells from a random A-positive dog in the same suspending medium; and (3) a 3 per cent suspension of red blood cells from the donor dog in normal saline. The tubes containing the rabbit serum and red-blood-cell suspension were then agitated gently, allowed to stand for fifteen minutes at room temperature, and centrifuged at 1,500 revolutions per minute. The tubes were then shaken gently and examined for agglutination with the aid of a magnifying mirror and reflected light, agglutination being read on the scale + to ++++.

† *Adsorption test:* Pooled, packed red blood cells from four A-negative dogs were washed four times in five times their volume of normal saline. After the last washing, the packed cells were added to the rabbit serum (in which the complement was inactivated) to be adsorbed in a 1:5 ratio; that is, 0.4 milliliter of cells were added to 2.0 milliliters of rabbit serum. The mixture of the rabbit serum and the dog red blood cells was then placed in an icebox, the tubes being gently agitated every fifteen minutes. After one hour, the mixture was centrifuged, the supernatant serum was transferred to a clean tube, and the cells were discarded. The adsorption process was repeated for a total of three times, fresh cells being added to the serum in the same ratio as before. The serum was then tested against A-negative cells and if adsorption was incomplete, as evidenced by agglutination, further adsorption was done until no agglutination was obtained, indicating complete adsorption. When adsorption was complete, the serum was tested for agglutinins against a 3 per cent suspension of red blood cells in normal saline from the donor A-positive dog. All cell suspensions that did not show agglutination with either unadsorbed or adsorbed serum were further tested with dog Coomb's serum (rabbit anti-dog globulin serum).

TABLE I

AGGLUTINATION TEST OF A-POSITIVE DOG RED BLOOD CELLS BY SERUM FROM RANDOM NON-OPERATED CONTROL RABBITS

| Experimental Animals | Undiluted | Agglutination Test Serum Dilutions<br>1:2 | 1:4 | 1:8 |
|---|---|---|---|---|
| Rabbit 1 | | | | |
| Dog 4 | + + + | + + | + | – |
| Dog 34 | + + + | + + | + | – |
| Rabbit 2 | | | | |
| Dog 30 | + + | – | – | – |
| Dog 34 | + | – | – | – |
| Rabbit 3 | | | | |
| Dog 43 | + + | + | – | – |
| Dog 34 | + + | – | – | – |
| Rabbit 4 | | | | |
| Dog 36 | + + | + | – | – |
| Dog 34 | + + | + | – | – |
| Rabbit 5 | | | | |
| Dog 45 | + + + | + + | + | – |
| Dog 34 | + + + | + + | + | – |

cells of the donor that was not contained in the adsorbing cells and, hence, not removed.

*Results of the agglutination tests* (Charts I, II, and III). In all three groups, there was a definite rise in titer of agglutinating antibody in the beginning of the twelve-week period and a fall toward the end. This was seen in the sera tested against random A-positive red blood cells, as well as against red blood cells from the bone of the A-positive donor dog. The use of autogenous dog serum in the red-blood-cell-suspending medium did not appear to enhance the agglutination reactions, since in both Group II and Group III the serum tested against red blood cells suspended in normal saline alone reached the highest titer.

To render the graphs more compact, the combined titers for each rabbit tested

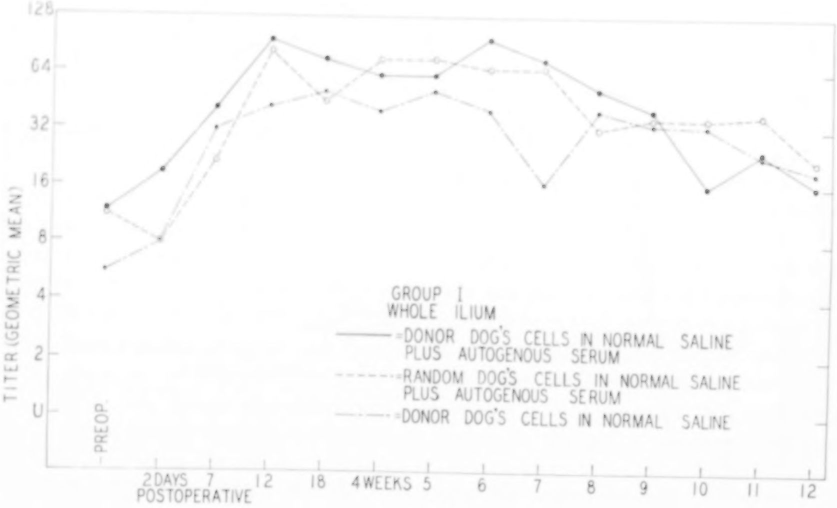


CHART I

(Reproduced by permission of The New York Academy of Sciences from *Annals of the New York Academy of Sciences*, **59:** 437, Jan. 1955.)

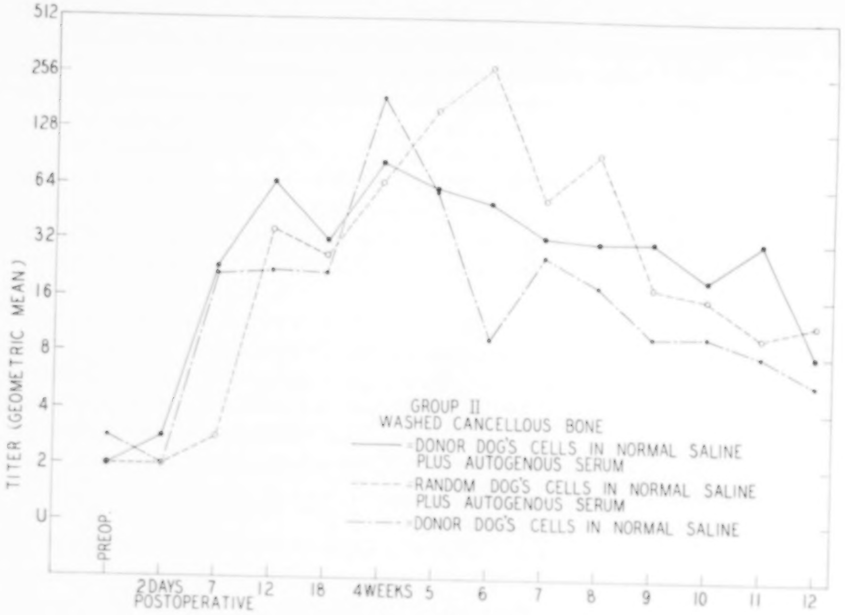


Chart II

(Reproduced by permission of The New York Academy of Sciences from *Annals of The New York Academy of Sciences*, **59**: 437, Jan. 1955.)

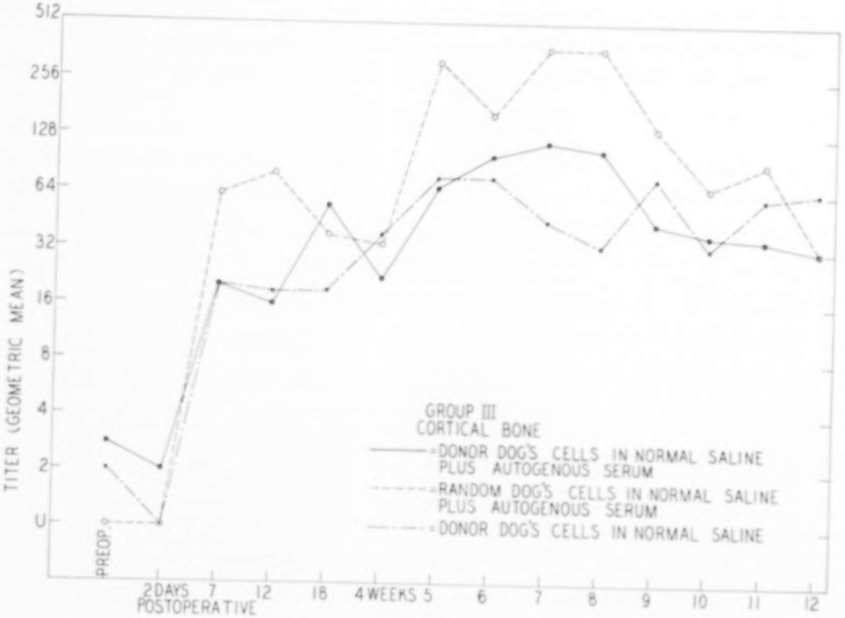


Chart III

(Reproduced by permission of The New York Academy of Sciences from *Annals of The New York Academy of Sciences*, **59**: 438, Jan. 1955.)

TABLE II

ADSORPTION TESTS ON SERUM OF OPERATED EXPERIMENTAL RABBITS

| Experimental Animals | Adsorption Tests: A-Negative Red Blood Cells: Adsorbed Serum | Adsorption Tests: A-Negative Red Blood Cells: Unadsorbed Serum | Adsorption Tests: A-Positive Red Blood Cells (Donor Dog): Adsorbed Serum | Adsorption Tests: A-Positive Red Blood Cells (Donor Dog): Unadsorbed Serum |
|---|---|---|---|---|
| Group I | | | | |
| Rabbit 57 | − | + | − | + |
| Rabbit 58 | − | + | − | + |
| Rabbit 59 | − | + | − | + |
| Rabbit 60 | − | + | − | + |
| Group II | | | | |
| Rabbit 37 | − | + | + | + |
| Rabbit 38 | − | + | − | + |
| Rabbit 39 | − | + | − | + |
| Rabbit 40 | − | + | − | + |
| Group III | | | | |
| Rabbit 42 | − | + | − | + |
| Rabbit 56 | − | + | − | + |
| Rabbit 41 | − | + | − | + |
| Rabbit 52 | − | + | − | + |

Coomb's Test—All negative

against each type of cell suspension are shown as geometric means *. This gives the most accurate average titer and will enable the curve of the rise and fall of the titers to be graphed, but does not readily show the actual titers that were obtained. In Group I, the highest individual serum titer reached was 1:1024; in Group II, it was 1:2048; and in Group III, it was 1:1024. When these highest individual serum titers were averaged with those of the other sera in their group, these individual high peaks still stand out.

*Results of the adsorption tests* (Table II). With one exception, no agglutination of A-positive cells was found after complete adsorption of the serum with pooled A-negative cells. These data suggest that the agglutinating antibody demonstrated was not directed against the canine A factor but, rather, had developed as a result of an antigenic stimulus by some other material present in dog erythrocytes or in the bone itself.

### *B. Dog Bone in Dogs*

*Problem:* Will the introduction of a large homogenous bone graft from a dog of A-positive blood type into a dog of A-negative blood type result in the production of antibodies against the red blood cells of the donor?

*Experimental method:* Five pairs of dogs were used, an A-positive dog (donor) and an A-negative dog (host) of approximately equal size and age constituting a pair. By means of the technique previously described [9], the left knee joints were interchanged. Serum was collected from the host dogs on the day of the operation and thereafter at intervals,—after two days, seven days, twelve days, eighteen days, and then weekly for a period of three months. The serum was stored after collection in a deep freeze at −20 degrees centigrade until completion of the time period. The serum samples were then tested against the red blood cells of the donor dogs for agglutination as previously described for the rabbits, the medium for the 3 per cent red-blood-cell suspension being composed of 50 per cent autogenous serum and 50 per cent normal saline.

---

* The geometric mean for each curve was arrived at as follows: The logarithm of the highest titer (that is, 2, 4, 8, 16, and so forth) for each time period was determined. These were added and then divided by the number of determinations, usually four. The antilogarithm of this figure was then found, and this number was used to represent the average titer for that time period.

TABLE III

ADSORPTION TESTS ON SERUM OF OPERATED DOGS

| | | Adsorption Tests | | | |
|---|---|---|---|---|---|
| | | A-Negative Red Blood Cells | | A-Positive Red Blood Cells (Donor Dog) | |
| Dog Number | Dog Serum Specimen Number | Adsorbed Serum | Unadsorbed Serum | Adsorbed Serum | Unadsorbed Serum |
| 55 | 1 | – | + + | + + | + |
| | 2 | – | + + | + + | + + |
| | 3 | – | + + | + + | + |
| | 4 | – | + + | – | + + |
| 42 | | | | | |
| | 1 | – | + | + + | + + + + |
| | 2 | – | + | + + + + | + + + + |
| | 3 | – | – | + + + + | + + + + |
| | 4 | – | + | + + + + | + + + + |
| | 5 | – | – | + + + + | + + + + |
| | 6 | – | – | + + + + | + + + + |
| | 7 | – | – | + + + + | + + + |

Of the five donor-host pairs operated upon, six dogs survived as pairs. In the other two pairs, fortunately, the A-negative dog survived and the collected serum was tested with red blood cells of a non-donor A-positive dog.

*Results of the agglutination tests* (Chart IV). Only two of the five A-negative dogs showed evidence of the development of an agglutinating antibody and in only one (CU 42) did it appear to be present in significant titer. Both of these were tested against red blood cells from the donor dog.

*Results of the adsorption test* (Table III). These were done on the pooled serum specimens from dogs CU 42 and CU 55, the only two which had shown evidence of the development of an agglutinating antibody. In both of these, however, in contrast with the findings

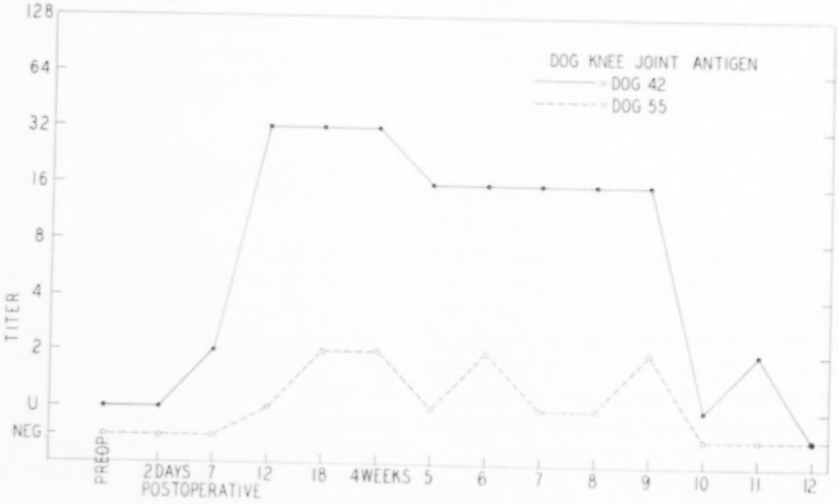


CHART IV

(Reproduced by permission of The New York Academy of Sciences from *Annals of The New York Academy of Scientists,* **59:** 440, Jan. 1955.)

in the rabbits, a strongly positive agglutination (+ + to + + + +) of A-positive cells was found (except in serum number 4, Dog 55), even after complete adsorption by the A-negative cells had been proved. This suggests that a specific antibody against the A substance had been formed, although the possible errors in this conclusion have been previously discussed.

## DISCUSSION

For detailed discussions of the problem of the homotransplantation of tissues other than bone, those interested may refer to several excellent sources [10,11,16]. The concept that an antigen-antibody reaction may be the major mechanism in unsuccessful homotransplantations is of course not new. This theory as applied to skin-grafting has been studied by many, but most thoroughly by Medawar [8,12,13]. He has proposed that resistance to homogenous skin grafts (in the rabbit) belongs in the general category of actively acquired immune reactions [12,13], and has suggested that its consequence is to upset the nucleus in such a way that cell division cannot be brought to completion. However, he has stated that the "crucial evidence of the existence of specific 'antibodies' directed against the cells of the foreign graft is still to be found" [15].

Loeb, one of the foremost investigators in this field, has proposed another possibility, —the presence of *individuality differentials:* ". . . there is a substance in the bodyfluids of one individual which responds towards all the cells and tissues of another individual in accordance with the genetic difference between these two individuals . . . . it is common to all the various tissues and organs of an individual." He has said, "the primary factors determining the fate of transplants are the differences in the individuality differentials of host and transplant, these differences being preformed and giving rise to relatively slow and mild but, in many instances, gradually accumulating primary reactions against the transplants."

The possibility of a relationship between blood types and the generally unsatisfactory results in homografting (except in bone, cornea, and cartilage) has been frequently proposed. Medawar [14] was not able to demonstrate red-blood-cell agglutinins following transplantation of skin in rabbits or any effect on homogenous grafts following transfusions of red blood cells, but he did demonstrate that intradermal injections of leukocytes from the donor into the host provoked a typical complete immune reaction toward subsequent skin grafts from the same donor. He suggested that "leukocytes share antigens in common with the antigens of the skin".

Although the authors believe that often "originality is undetected or unknowing plagiarism", they have not been able to find in the literature any experimental studies concerning a blood-group effect on bone homografting. However, in a series of excellent articles [1–5], Candela demonstrated that it is possible to "type" bone by means of a meticulous adsorption technique. With this method, he was able to correctly identify the blood type of nine of ten test specimens submitted to him [5]. He also described the successful "typing" of bone of Egyptian partial skeletons 3,500 years old [1]. However, his target material was cancellous bone as "it is highly probable that the specific adsorption which makes these tests possible is accomplished entirely by the organic residues of the blood-forming elements of the red marrow, and of blood itself, remaining *in situ* after death" [2]. It is well known that human A and B group-specific substances are widely distributed in the tissues of persons with these types, but those substances have not been demonstrated in bone devoid of cellular elements. It does seem extremely unlikely that a tissue which is only 30 per cent organic could act as much of an antigen, but much work remains to be done on the antigenic potentials of bone's organic constituents.

Practically, however, when one employs bone in homografting, it is as an organ, complete with marrow and other cellular elements rather than as an acellular tissue. Whether the contained cells are alive or dead is unimportant, as the A and B group-specific substances are very persistent and could function, theoretically at least, as potential antigens. In two of the rabbit experiments described, an attempt was made to remove most of these cellular elements, but the claim is not made that removal was complete. However, an agglutinin titer developed as readily in these animals as in those in which whole ilium with its richly cellular marrow was placed.

## SUMMARY

1. The intramuscular insertion in the rabbit of whole iliac bone, washed iliac bone, and cortical bone from an A-positive dog resulted in the formation of high-titer agglutinins against dog red blood cells. Adsorption tests did not demonstrate any specificity of these agglutinins for the canine A factor in dog red blood cells.

2. In two of five A-negative dogs in each of which was transplanted a knee joint from an A-positive dog, low-titer agglutinins against the donor dog's red blood cells developed. Adsorption tests on the sera of these two dogs suggest the possible specificity of the agglutinins for the canine A substance, although the possibility of the agglutinin being due to a factor other than the canine A factor was not excluded.

3. Transplanted dog bone or its contained cellular elements appears to act as an antigen, but no relation between that action and the blood type of the donor dog could be established with certainty.

ACKNOWLEDGMENTS: Through the kindness of Dr. Lawrence E. Young and Dr. William A. O'Brien of the University of Rochester Medical School, a supply of anti-A serum was obtained which was used to type and classify dogs into A-positive and A-negative groups.

The authors wish to express their appreciation to Mrs. Charlene Heath, Mrs. Jane Saxton, and Mr. David Jones for their technical assistance in these studies.

## REFERENCES

1. CANDELA, P. B.: Blood-Group Reactions in Ancient Human Skeletons. Am. J. Phys. Anthropol., **21:** 429–432, 1936.
2. CANDELA, P. B.: Blood Group Determinations upon Minnesota and New York Skeletal Material. Am. J. Phys. Anthropol., **23:** 71–78, 1937.
3. CANDELA, P. B.: Blood-Group Determinations upon the Bones of Thirty Aleutian Mummies. Am. J. Phys. Anthropol., **24:** 361–383, 1939.
4. CANDELA, P. B.: Blood-Group Tests on Stains, Mummified Tissues, and Cancellous Bone. Am. J. Phys. Anthropol., **25:** 187–214, 1939.
5. CANDELA, P. B.: Reliability of Blood-Group Tests on Human Bones. Am. J. Phys. Anthropol., **27:** 365–381, 1940.
6. CANDELA, P. B.: Personal communication.
7. CHRISTIAN, R. M.; ERVIN, D. M.; YOUNG, L. E.: Observations on the In-Vitro Behavior of Dog Isoantibodies. J. Immunol., **66:** 37–50, 1951.
8. GIBSON, T., and MEDAWAR, P. B.: The Fate of Skin Homografts in Man. J. Anat., **77:** 299–310, 1943.
9. HERNDON, C. H., and CHASE, S. W.: Experimental Studies in the Transplantation of Whole Joints. J. Bone and Joint Surg., **34-A:** 564–578, July 1952.
10. LOEB, LEO: The Biological Basis of Individuality, pp. 5–7. Springfield, Illinois, Charles C. Thomas, 1945.
11. LONGMIRE, W. P., JR., and SMITH, S. W.: Homologous Transplantation of Tissues. A Review of the Literature. Arch. Surg., **62:** 443–454, 1951.
12. MEDAWAR, P. B.: The Behaviour and Fate of Skin Autografts and Skin Homografts in Rabbits. (A Report to the War Wounds Committee of the Medical Research Council). J. Anat., **78:** 176–199, 1944.
13. MEDAWAR, P. B.: A Second Study of the Behaviour and Fate of Skin Homografts in Rabbits. (A Report to the War Wounds Committee of the Medical Research Council). J. Anat., **79:** 157–176, 1945.
14. MEDAWAR, P. B.: Relations between Antigens of Blood and Skin. Nature, **157:** 161–162, 1946.
15. MEDAWAR, P. B.: A Biological Analysis of Individuality. Am. Scientist., **40:** 632–639, 1952.
16. WILLIS, R. A.: The Experimental Study of Tissue Transplantation and Its Bearing on Surgery. Australian and New Zealand J. Surg., **9:** 119–146, 1939.
17. YOUNG, L. E.; O'BRIEN, W. A.; SWISHER, S. N.; MILLER, GERALD; YUILE, C. L.: Blood Groups in Dogs. Their Significance to the Veterinarian. Am. J. Vet. Res., **13:** 207–213, 1952.
18. YOUNG, L. E.: Personal communication.

# REPAIR OF DEFECTS IN THE TENDO ACHILLIS *

BY DAVID M. BOSWORTH, M.D., NEW YORK, N. Y.

It has long been conceded that repair of defects in the tendo achillis by replacement with fibrous tissue is unsatisfactory. Fibrous tissue interposed in the defect has been shown to stretch gradually and to be unable to withstand the stress imposed upon it by the calf muscles. It was for this reason that, long ago, subcutaneous tenotomy of the tendo achillis was discarded as an operative procedure and lengthening of the tendo achillis by double "L" incisions or other open techniques was substituted. It was known that if even a small amount of tendinous tissue completely and firmly bridged the gap, re-formation of normal tendon would occur from the interposed remnants. Spontaneous bridging of the gap by tendinous tissue between the separated ends, following either rupture or operative division, uniformly fails to occur.

We recognize that a sharp line of distinction must be drawn between immediate repair of fresh ruptures of the tendo achillis and delayed repair or repair of old ruptures. Actually, contracture of the calf muscles occurs very rapidly, so that within three or four days difficulty may be experienced in regaining coaptation of the ruptured ends of the tendon. Furthermore, following rupture, the tendon ends may be so shredded that an actual loss of length has been established in the tendinous apparatus so that if coaptation is to be gained, repair must be accomplished with shortening of the tendinous structure to less than its original length. Therefore, even in immediate repair of fresh ruptures, we would feel that some transplanation of tendinous structure across the area of rupture is indicated, in addition to its resuture. Resuture, if done, without the use of tendinous material in the repair probably should be supported with pull-out wires, as advocated by Bunnell, in addition to plantar flexion of the foot and fixation in a plaster boot.

Delayed repair or repair of old defects presents an entirely different problem. Many types of repair using fascia lata or other tendinous structures have been carried out in the past. The method of repair of these old lesions suggested herewith depends upon an anatomical fact apparently not commonly appreciated. This method has been employed in six patients in the past twenty-one years. In all six the calf musculature is now normal compared with that of the opposite side, with no measurable atrophy or any loss in length of the tendo achillis. The range of motion of the joints and the outline of the calves are normal. Restoration of the hypertrophied tendon to normal size occurred in three patients. Persistence of slight enlargement at the defect was noted in three patients.

The first patient was fourteen months of age at time of repair in 1934. The defect had been present for eight months. Lengthening of the tendo achillis with double "L" incisions had been done, with apparent avulsion of one end of the lengthened tendon. A fibrous defect occurred in the gap. He had been treated for bilateral club-foot deformity, with complete correction of the varus element of the deformity, preceding a bilateral heel-cord lengthening. Repair of the defect resulted in a normal foot and leg, twenty-one years later.

The other five patients were between thirty and thirty-eight years of age at the time of repair. In four of them laceration of the tendon had occurred in jumping accidents; one had been kicked in the tendo achillis when it was on stretch. Repair was done from one to fourteen months following injury. They have been followed for nine years in one instance, seven years in two instances, five years in one, and five months in the last. All have recovered with normal findings as to the calf musculature, although three have slight enlargement at the point of repair. All are without symptoms and none of them have any limp, subjective weakness, or other difficulty.

---

* Read before the Orthopedic Section of the New York Academy of Medicine, February 21, 1955.

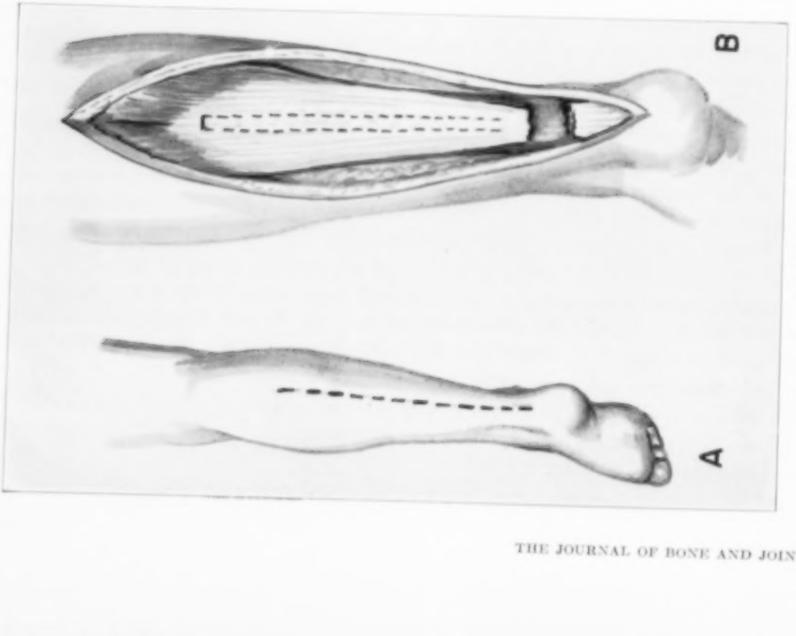


Fig. 1

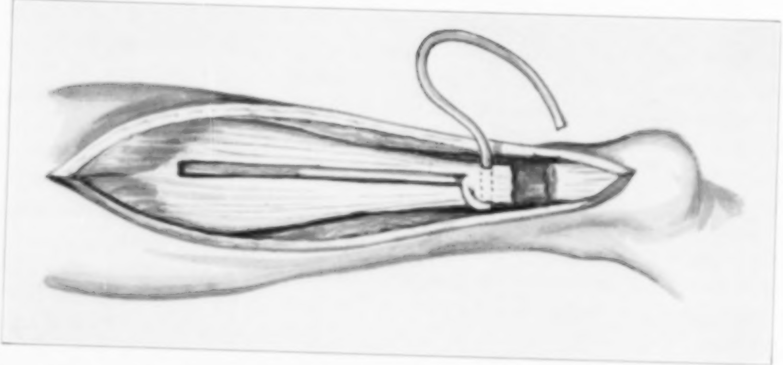


Fig 2

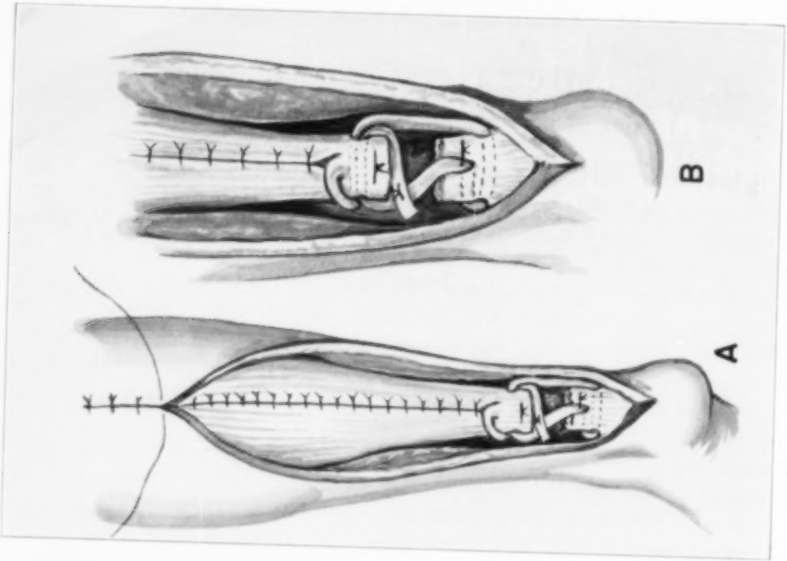


Fig. 3

Fig. 1, *A:* The line of incision on the posterior portion of the calf.

Fig. 1, *B:* The outline of the area of excision of a one-half inch strip of tendon from the proximal part of the raphe of the tendo achillis is shown. This extends upward into the lower portion of the calf. Note that the strip is turned downward and is left attached below, just above the proximal end of the lacerated tendo achillis. Fibrous tissue in the defect between the ends of the tendo achillis has been removed.

Fig. 2: The tip of the strip of tendon which was turned down has been passed transversely through the proximal end of the lacerated tendo achillis. This is to prevent its tearing out of the end of the proximal portion of the tendo achillis. This part of the stitch should be fastened with one or two chromic sutures.

Fig. 3, *A:* After passing transversely through the proximal end of the lacerated tendo achillis, the tendon strip has been brought downward and passed transversely through the distal end of the tendo achillis, and then forward through the distal stump, drawn tight, and sutured. It has then been passed upward and again transversely through the proximal end of the tendo achillis, drawn tight, and sutured; and then passed downward and sutured to itself. Note that the defect in the posterior raphe on the lower portion of the calf and upper tendo achillis has been closed with interrupted sutures and the skin is being closed.

Fig. 3, *B:* Enlarged diagram to show the passage of the tendon as it is woven between the two ends of the ruptured tendo achillis bridging the gap therein.

---

All six patients noted in the foregoing were males, and three had laceration of the right tendo achillis and three of the left.

In contrast with these patients is another who was operated upon in 1933. The rupture of the tendo achillis occurred while she was jumping in a gymnasium. Four days following rupture, repair was attempted, but a retraction of the calf muscles had already occurred to such an extent that the gap could not be closed with full plantar flexion of the foot. Since the rupture was in the upper portion of the tendon the lower portion was lengthened by means of double "L" incisions, and the gap was thereby crossed. Recovery to a completely normal calf as to outline and power and to a normal tendo achillis apparatus has occurred. The last follow-up examination was twenty-two years later. The patient is reported to show how rapidly fixed retraction of the calf musculature can occur.

## OPERATION PROPOSED

The basis of the operative repair which we have used since 1934 is the anatomical fact that the raphe of the tendo achillis extends upward on the posterior surface of the calf muscles, three-fifths of the way from the heel to the knee. A vertical incision over this area through the skin and soft tissue can expose the tendo achillis and the upward extension of the tendinous raphe. Incising and freeing a one-half inch strip from the central portion of this raphe from above downward, which is left attached to the proximal end of the tendon just above the defect, provides a section of tendinous tissue from seven to nine inches in length (Fig. 1). Closure of the defect left in the calf with interrupted sutures reconstitutes the lower calf muscles and the upper portion of the tendo achillis. The strip of tendon, turned downward, is then passed transversely through the proximal end of the ruptured tendo achillis in order to imbricate it there and to prevent its pulling out. One or two chromic sutures should be passed through this area to further fix it. The fibrous tissue interposed between the actual tendon ends should be removed. The strip of tendon is passed transversely through the distal end of the tendo achillis beyond the defect and is then passed through this same distal end from behind forward. It is drawn tight, and this area is sutured with chromic catgut to prevent the strip from tearing out. The strip is brought upward and is passed transversely again through the proximal end of the tendo achillis and is drawn tight, fixed with one or two chromic sutures, and brought down and again sutured to itself (Fig. 3).

The above procedure should be carried out with the foot in plantar flexion since one will later wish to draw the calf muscles down as nearly into the normal position as possible. The tendon graft crossing the defect does not have sufficient strength to resist the forces imposed by the calf muscles, but merely acts as a bridge of continuity of tendinous tissue of the same texture as the original tendo achillis between the separated ends. Following plaster encasement with the foot in plantar flexion, and with non-weight-bearing for six weeks, marked hypertrophy of tendinous structure occurs. During another six weeks, spent in gradually reestablishing weight-bearing, gradual decrease in size of this reparative tendinous mass is noted to occur. Full weight-bearing was permitted in these patients approximately three months after operation. It can be noted from the patients in this series that the tendon eventually returns to essentially its normal size.

The cases presented are few, but their follow-up, except for the last case, appears adequate. No operative complications have been experienced. No physical therapy, aside from warm baths and massage done by the patients themselves in their homes, has been employed. Reconstitution of the calf muscles both as to size and outline has been good. Secondary incisions are avoided by this method, removal of other tendinous structures to secure tendinous repair has proved unnecessary, and the employment of fascia lata or a similar structure with its inherent tendency to stretch under stress has been unnecessary.

## CONCLUSIONS

Repair of old defects in the tendo achillis demands crossing the gap with new tendinous tissue.

A repair using the tendo achillis itself has been suggested.

# HEMANGIOMATOSIS OF THE SKELETON AND THE SPLEEN *

BY GORTON RITCHIE, M.D., MILWAUKEE, WISCONSIN, AND FRANCIS G. ZEIER, M.D.,
ROCKFORD, ILLINOIS

*From the Milwaukee Children's Hospital, Milwaukee*

Although silent hemangiomata of the vertebrae have been reported as frequent findings at autopsy [23] and although there are several references in the literature to the presence of these tumors in the flat bones and in the long bones [12, 25], reports of generalized involvement of the skeleton have been rare. Reports of cases in which hemangiomata were present in the spleen as well as throughout the skeleton have been rarer still. The authors' case is presented here to call further attention to the latter entity.

In a review of the cases of vascular tumors of the bone listed at the Registry of Bone Sarcoma of the American College of Surgeons, Thomas asserts that benign vascular tumors of the bone possess certain roentgenographic and pathological features which are diagnostic. He feels that it is justifiable to consider vascular tumors as a special class of bone tumors.

Hemangioma of bone is rare as a clinical entity, but it is not rare as a pathological finding [5, 9, 14]. In 1928 Töpfer reported that vertebral hemangiomata were found in 11.9 per cent of 2,154 autopsies. The site in which hemangiomata most often occur is the spinal column, where multiple vertebrae may be involved [23]. The next most common site is the skull [12], where they may be related to similar lesions in the meninges and scalp [8]. In a recent review of the literature, Jacobs and Kimmelstiel estimated that the total number of reported cases of extravertebral hemangiomata of the bone, including their own two cases, was forty-one; twenty of these cases involved the skull and twenty-one the bones of the extremities. They were unable to find more than seventeen cases in which there were multiple benign angiomata involving the skull and the extremities, and they found no cases in which there existed angiomatosis of the skeleton comparable to that found in their two cases. We have found one other case, that of Parsons and Ebbs, which may be classed with those of Jacobs and Kimmelstiel; and our own unusual case, which has the additional feature of hemangiohamartoma of the spleen, may also be classed in this group.

The roentgenographic appearance of benign hemangiomata of bone is fairly characteristic [5]. In flat bones, such as the scapula, in the pelvis, and in the skull, there is a sunburst pattern formed by new bone radiating from a point on the surface. Some hyperostosis may also be present [2, 10]. In the spinal column there are coarse, dense vertical striations on the bodies, and compression of the spinal cord [3, 25] and even of the bodies themselves [14] has been reported. The coarse trabeculations may extend into the vertebral arch. In the tubular bones hemangiomata occur chiefly in the epiphyses near the entrance of the nutrient arteries [1, 5], and they may be subperiosteal or medullary but are always eccentric. A typical roentgenogram of a tubular-bone tumor shows multilocular cystic cavities of various sizes and irregular shapes. The appearance of this tumor somewhat resembles the well known soap-bubble appearance of a giant-cell tumor of bone [8], but the loculi are smaller than those in the giant-cell tumors and bone cysts and their framework is heavier. Within the loculi there is a fine fibrillary framework [1]. There may be a local or general uniform spindle-shaped expansion of the shaft of the involved tubular bone, and the cortex of this bone may be very thin, although it is usually intact [1].

Benign hemangiomata are of two types, capillary and cavernous. The capillary variety are made up of closely-packed, small blood vessels which are lined by a single layer of nearly cuboidal endothelial cells. The cavernous type is composed of larger blood-filled spaces which are lined by a single layer of flattened endothelial cells. Elastic fibers and smooth muscle are usually not present in the walls of these tumors, and the amount and character of their fibrous supporting stroma varies greatly [21]. In cavernous hemangiomata, which are the most common of the two types, the connective-tissue stroma is compressed and restricted to a thin layer between the spaces [19] (Figs. 6 and 7), and there are no mitotic figures [11] and no capsule [14]. Benign hemangiomata may undergo spontaneous regression and healing [22], and osteoblastic activity may replace the vascular tissue with bone [14]. About the expanded vascular channels of the bone there may be evidence of absorption and deposition of bone [3, 25] and also sometimes of compensatory bone formation [25]. Instead of healing there may be gradual enlargement of the lesions, not as a result of intrinsic growth, but as a result of expansion due to intravascular tension; in such cases the shell of bone may become paper thin [5]. The periosteum of the bone is not perforated by these tumors, but it often expands to accommodate them. These tumors sometimes pulsate [4, 10].

---

* Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Los Angeles, California, January 30, 1955.

Opinion is divided as to whether benign hemangiomata represent congenital malformations, such as the hamartoma of Albrecht, or true neoplasms [7, 12, 22, 24]. Ribbert contends that although they are congenital in origin, they are nevertheless true neoplasms, and he claims that they grow independently from their own vascular substance, sometimes invading the surrounding structures. The concept that they are congenital malformations is favored by Shafer, who claims that over 50 per cent are present at birth. In the embryo there is a vast plexus of primitive vascular channels; gradually certain of these channels carry more and more of the blood with the result that in time a definitive circulatory system is formed. The alternate vascular channels usually disappear, but occasionally they persist as capillary or cavernous plexiform masses, maintaining connection with the definitive circulation by means of afferent and efferent vessels.

Grossly the biopsy specimen of a lesion in the long bones resembles that of a simple cyst of the bone, the cavities in this lesion being lined with a thin grayish-yellow membrane and containing serosanguineous fluid. Some of the cavities appear to be empty. A segment of an involved rib taken at biopsy is usually irregular in contour, expanded in places, and nodular on the surface. The expanded and nodular portions of such a bone are sometimes discolored blue, and a section of such a bone reveals the presence of multiple cystic spaces, some empty and some hemorrhagic. The hemorrhagic spaces contain a red-brown gelatinous substance. In an autopsy of their patient Parsons and Ebbs found remnants of lining endothelium in the bone marrow, indicating that at one time cavernous angiomatous spaces had been present. Hemangiomata are thought to be responsible for spontaneous hemorrhage in the structures in which they are located [21], and Pommer's theory that solitary bone cyst is the end result of an intramedullary hematoma is widely held. According to this theory, the increase in pressure incidental to localized hemorrhage causes the acceleration of osteoclasia and a circumscribed area of bone is absorbed. Jacobs and Kimmelstiel offer the hypothesis that simple bone cysts may be pathogenically related to angiomatous lesions.

Hemangiomata of the spleen, although rare, have been described [7, 13]. The most common variety is the cavernous type. This type gradually enlarges the spleen and bulges from its surface, becoming so large that the spleen is finally perched on the tumor. There is a tendency for these tumors to undergo extensive thrombosis [6]. A few cases in which hemangiomata of the bone were associated with splenic angiomata have been reported [17, 18], and in Parsons and Ebbs' unusual case of hemangiomatosis not only the bones, but also the thymus, lungs, liver, spleen, pericardium, lymph nodes, and kidneys were involved; the spleen was sponge-like with cavernous spaces occupying about two thirds of its volume. Hemangiomata have been considered as one of the varieties of true cysts of the spleen, being endothelial lined [7, 15], and changes in and bleeding from these lesions may conceivably give rise to hemorrhagic or false cysts in the spleen [24]. Symptoms of these tumors occur in patients as the results of local pressure, the stomach being displaced medially and the colon antero-inferiorly. Shock and death from hemorrhage may result from trauma.

## CASE REPORT

A white male, two years of age, was treated in May 1951, for a fracture of the left clavicle. This fracture had been discovered by his mother while she was bathing him. There was no history of an injury. The fracture healed promptly.

The boy was admitted to the Milwaukee Children's Hospital on October 5, 1951, for diagnosis. Six days earlier he had fallen when his right foot became tangled in a rug at home. Thereafter he had complained of pain in his right ankle and had limped, putting the right foot down in a position of equinus and bearing weight on it only in that position. During the previous month there had been a vague complaint of urinary frequency.

His past history was essentially negative, and his family history was non-contributory. His mother was subject to recurrent phlebitis, his father had leg ulcers, and one sibling had rheumatic fever. The other ten siblings were living and well (the patient was the last of the twelve siblings).

The physical examination revealed that he was a well-developed, well-nourished boy (Fig. 1). His weight and height were normal for his age; he appeared healthy and had no fever. A palpable firm mass with a notch extending four to six centimeters was found inferior to the left costal margin, suggesting splenomegaly. Some enlargement of the distal end of the right tibia was also found. The optic fundi were clear, and the results of the neurological examination were negative. A needle biopsy revealed hyperplastic bone marrow.

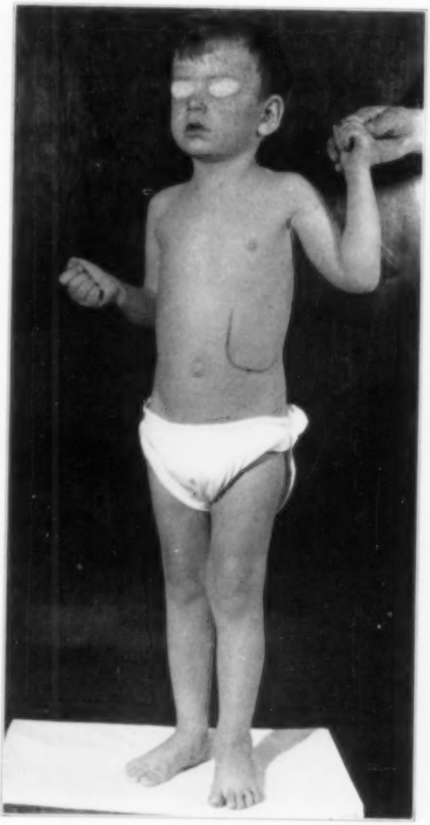


FIG. 1

This boy, who is two and one-half years of age, appears healthy. The pencil mark on the skin just below the left costal margin indicates the palpable margin of the spleen.

### *Laboratory Findings*

The hemogram revealed slight hypochromic anaemia, but the blood chemistry determinations, including calcium, phosphorus, and phosphatase, were all within normal limits. The urinalysis showed no remarkable deviation from the normal except for the presence of hemolytic *Staphylococcus aureus*. The results of routine agglutination tests and of the Kline, Mantoux, and histoplasmin tests were negative. The sedimentation rate, coagulation time, and bleeding time were also normal. A biopsy of the bone marrow revealed hyperplasia.

### *X-Ray Findings*

Multiple irregular, multilocular, and monolocular cystic lesions were found generally distributed throughout the skeleton, except in the epiphyses and in the bones of the hands and feet (Figs. 2, 3, 4, and 5).

*Skull:* Cystic areas that were as much as 1.5 centimeters in diameter were present in the diploe of the frontal and parietal bones. These areas had a moth-eaten appearance and were associated with some thinning of the tables. Similar involvement existed in the angles and rami of the mandible.

*Ribs:* There were multiple cystic lesions in the ribs. These lesions were oval in shape and caused expansion of the ribs in the involved portions.

*Vertebrae:* There was a suggestion of vertical striation in a few of the centra.

*Pectoral and pelvic girdles:* Cystic lesions were identified in the left clavicle, in the subcervical regions of the scapulae, in the iliac bones, and in the superior rami of the pubes.

*Extremities:* There was a wide-spread cystic involvement of the diaphyseal and metaphyseal portions

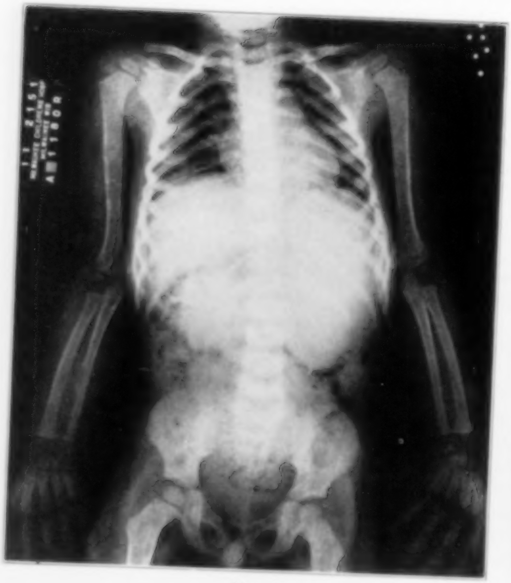


FIG. 2

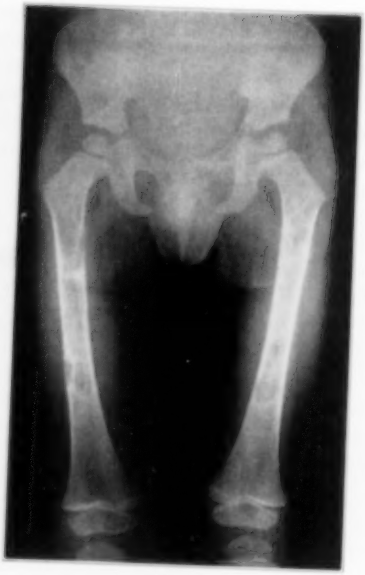


FIG. 3

Fig. 2: Roentgenogram of the trunk showing the enlargement of the kidneys and the spleen. Cystic defects are visible in the left clavicle, ribs, both humeri, both radii, right ulna, and pelvis.

Fig. 3: Multiple areas of increased radiolucency are evident in the pelvis and in the diaphyseal regions of the femora. Thinning of the cortex and local expansion of the bone can be seen.

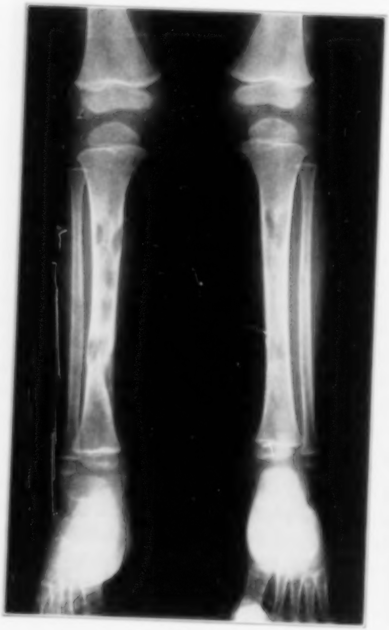


FIG. 4

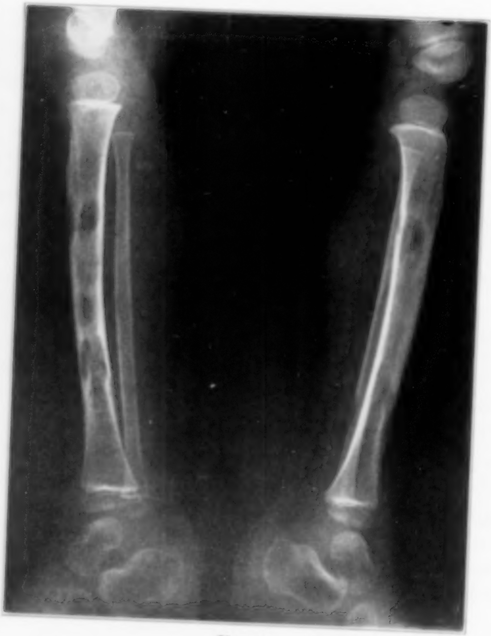


FIG. 5

Fig. 4: Multiple unilocular and multilocular cystic lesions are present in the bones of both legs. The cortices are intact, but there has been local expansion of the bones. Some trabeculation is present in the lesions.

Fig. 5: Lateral views of the tibiae shown in Figure 4.

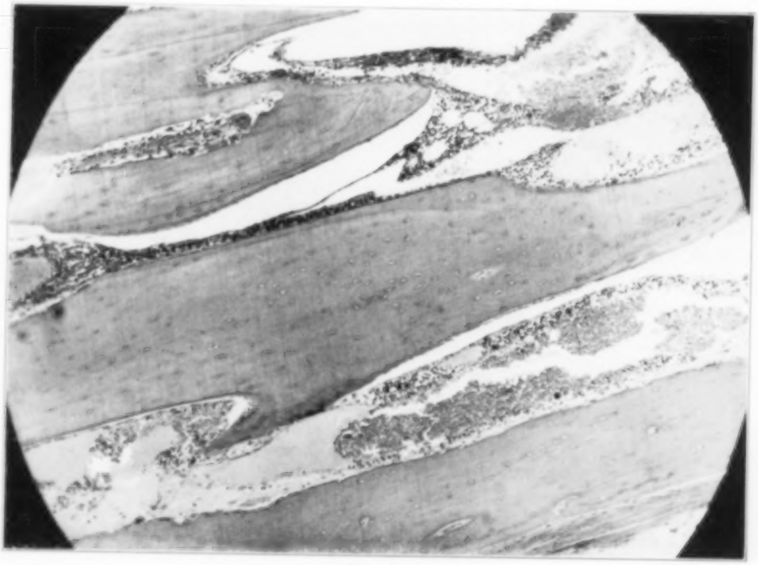


FIG. 6

A low-power photomicrograph of tissue taken at biopsy from a lesion in the rib. The fairly thick bone trabeculae are separated by thin-walled, endothelial-lined cavernous vascular spaces which contain blood. There is a minimal amount of marrow.

of the long bones. The lesions appeared to be both multilocular and unilocular and measured up to 2.5 centimeters in diameter. They were oval and elliptical in shape, and their long dimensions were oriented in the same direction as the long dimensions of the bones. They were intramedullary and intracortical and caused thinning of the cortex, although this thinning was incomplete and occurred only at the levels involved. No perforation of the cortices was seen. There was local expansion of the long bones, the diameter of the affected segments being enlarged; and there was a fissure fracture through a lesion in the right tibia.

*Abdomen:* A flat plate revealed that the kidneys and the spleen were enlarged. Intravenous pyelograms revealed distention of the calyces of the right kidney, but the excretion of dye from both kidneys was normal.

Retrograde pyelograms revealed hydronephrosis in the right kidney and slight hydronephrosis in the left. A slight ureteral obstruction was also present in the right kidney. This obstruction was about five centimeters proximal to the bladder.

### *Biopsy of Bone Lesions*

On October 12, 1951, a biopsy of the right tibia was performed. The cortex over one of the lesions was found to be thin and brittle, but intact. It showed increased vascularity and, when tapped, produced a hollow sound. The marrow of the involved bone was replaced by a poorly organized sinus filled with blood. Cultures of the tissue were negative, and the histological evidence was inconclusive.

On December 11, 1951, another biopsy was performed. The left seventh rib was resected along with some of its periosteum. There were a few bluish nodules on this rib, and the cortex was thin and translucent, although intact. The average diameter of the rib was 0.8 centimeter, but in a gross section taken from one of the bulging portions of the rib, a cystic lesion was found which measured 1.5 by 0.8 by 0.6 centimeters. No trabeculae traversed this cyst, and the marrow in the involved bone was loose and soft and contained blood clots (the marrow in the uninvolved bone was firm and of a pale red-brown color). A microscopic examination of the other lesions in this rib revealed that in general the marrow of the involved bone had been replaced by widely dilated, extremely thin-walled blood spaces (Figs. 6 and 7). Around the central part of each lesion the cortex was thickened on one surface and thinned on the other, and the contents of these central portions were almost entirely hemorrhagic. The diagnoses were vascular malformation, hamartoma, and hemangioma of the bone.

### *Laparotomy for Splenomegaly*

On June 12, 1952, a laparotomy was done. The liver and kidneys appeared to be normal, but the spleen was found to be enormously enlarged and was estimated to be at least eight times its normal size. It contained what appeared to be multiple cystic tumors. One of these cystic nodules was aspirated with the

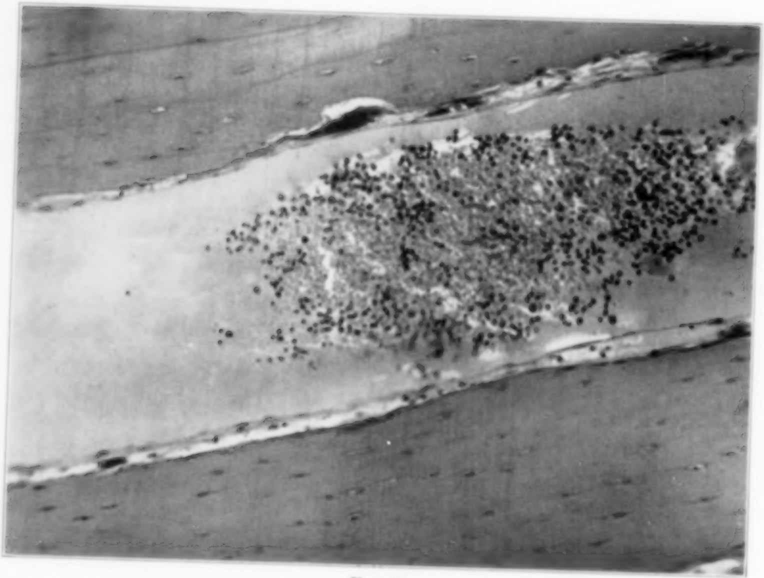


FIG. 7

A high-powered photomicrograph of tissue biopsied from a lesion in the rib. The large thin-walled endothelial-lined vascular space in the bone contains blood and serum.

spleen *in situ* and a yellowish serous fluid was obtained. A splenectomy was then performed, from which the patient made an uneventful recovery.

A pathological study of the removed spleen was made. When the blood had been drained from the splenic vein, the spleen measured fourteen by 9.3 by 4.5 centimeters. The color of the spleen with the capsule

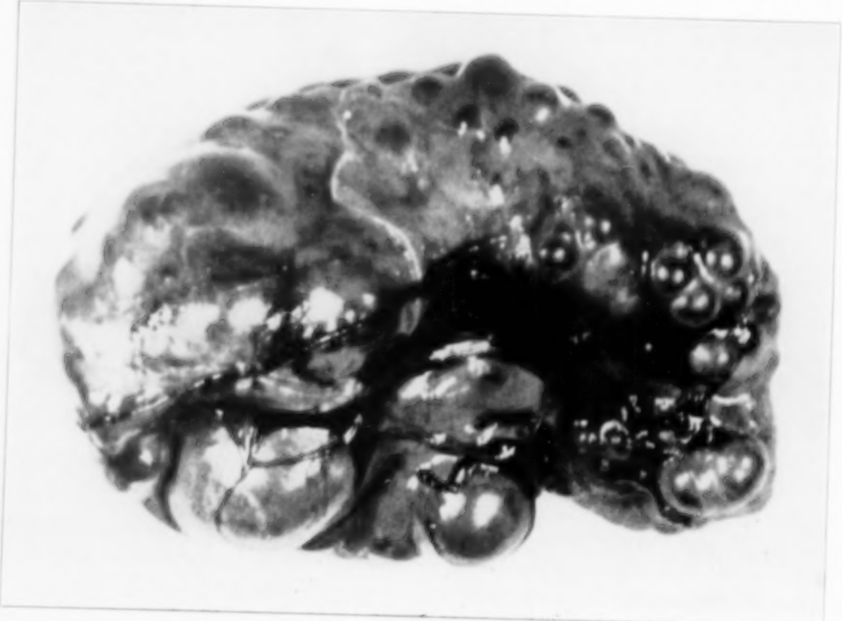


FIG. 8

A photograph showing cystic angiomatosis of the spleen. The gross specimen resembles a cirrhotic liver or a polycystic kidney.

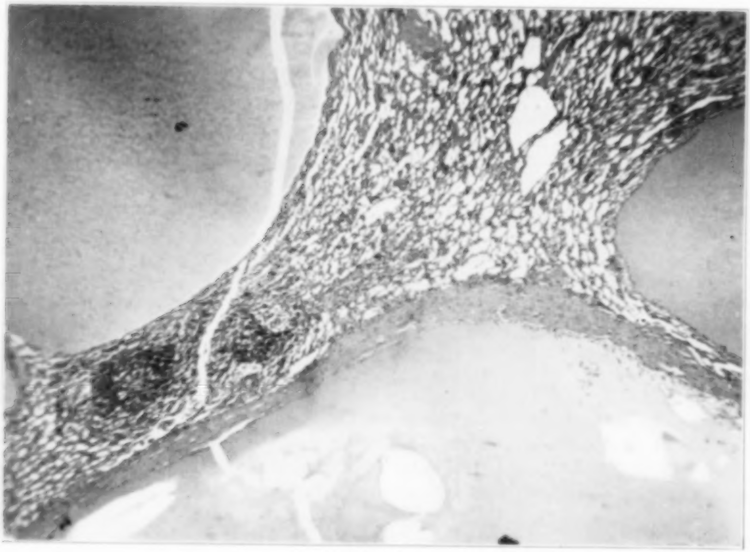


FIG. 9

A photomicrograph of the spleen showing compressed splenic pulp and enlarged cystic cavernous vascular areas which are filled with blood and serum.

present was medium red-gray, and its surface was irregular and studded with innumerable cystic nodules; these nodules measured up to three centimeters in diameter (Fig. 8). The fluid aspirated from one of the cysts was yellow and contained erythrocytes. When allowed to stand in a test tube, it immediately formed a coagulum. The cut surface of the spleen contained similar cystic areas.

A histological examination of the spleen revealed that small areas of apparently normal splenic tissue were present. It also revealed that almost the entire organ was tremendously distended, containing vascular spaces in which there were a few erythrocytes and a large amount of hyaline protein precipitate (Fig. 9). The larger spaces were walled with fibrous connective tissue, and the smaller abnormal spaces appeared to have developed more or less from venous sinuses and to be merging somewhat with the normal vascular structure of the spleen. The corpuscles were hyperplastic. The diagnosis was hemangiohamartoma of the spleen.

## CONCLUSION

The patient has been followed for over three years, and during this time his general health has been good. Three fractures have occurred through lesions, one in the right humerus (May 13, 1954), one in the right tibia (June 17, 1955), and one in the right femur (July 10, 1955). The accidents which caused these fractures would probably be insufficient to break normal bones. The fractured humerus was treated by a hanging cast and healed readily. The patient is still under treatment for the tibial and femoral fractures.

NOTE: Acknowledgment is made to Dr. Walter P. Blount and to Dr. Phillip H. Seefelt for their assistance. The patient was on the former's service, and the splenectomy was performed by the latter.

## REFERENCES

1. ACKERMANN, A. J., and HART, M. S.: Multiple Primary Hemangioma of the Bones of the Extremity. Am. J. Roentgenol., **48:** 47–52, 1942.
2. ANSPACH, W. E.: Sunray Hemangioma of Bone. With Special Reference to Roentgen Signs. J. Am. Med. Assn., **108:** 617–620, 1937.
3. BAILEY, PERCIVAL, and BUCY, P. C.: Cavernous Hemangioma of the Vertebrae. J. Am. Med. Assn., **92:** 1748–1751, 1929.
4. BRAILSFORD, J. F.: The Radiology of Bones and Joints. Ed. 4, p. 710. Baltimore, the Williams and Wilkins Co., 1948.

5. Bucy, P. C., and Capp, C. S.: Primary Hemangioma of Bone. With Special Reference to Roentgenologic Diagnosis. Am J. Roentgenol., **23:** 1–33, 1930.
6. Foot, N. C.: Pathology in Surgery, p. 176. Philadelphia, J. B. Lippincott Co., 1945.
7. Fowler, R. H.: Cystic Tumors of the Spleen. Internat. Abst. Surg., **70:** 213–223, 1940.
8. Geschickter, C. F., and Copeland, M. M.: Tumors of Bone. Ed. 3, pp. 613–620, 639. Philadelphia, J. B. Lippincott Co., 1949.
9. Geschickter, C. F., and Maseritz, I. H.: Primary Hemangioma Involving Bones of the Extremities. J. Bone and Joint Surg., **20:** 888–900, Oct. 1938.
10. Kaplan, Abraham, and Kanzer, Mark: Sunray Hemangioma of the Skull. Report of a Case. Arch. Surg., **39:** 269–274, 1939.
11. Karshner, R. G.; Rand, C. W.; and Reeves, D. L.: Epidural Hemangioma Associated with Hemangioma of the Vertebrae. Report of a Case. Arch. Surg., **39:** 942–951, 1939.
12. Jacobs, J. E., and Kimmelstiel, Paul: Cystic Angiomatosis of the Skeletal System. J. Bone and Joint Surg., **35-A:** 409–420, Apr. 1953.
13. Ladd, W. E., and Gross, R. E.: Abdominal Surgery of Infancy and Childhood, p. 256. Philadelphia, W. B. Saunders Co., 1941.
14. Luck, J. V.: Bone and Joint Diseases. Pathology Correlated with Roentgenological and Clinical Features, pp. 470–473. Springfield, Illinois, Charles C. Thomas, 1950.
15. McClure, R. D., and Altemeier, W. A.: Cysts of the Spleen. Ann. Surg., **116:** 98–102, 1942.
16. Parsons, L. G., and Ebbs, J. H.: Generalized Angiomatosis Presenting the Clinical Characteristics of Storage Reticulosis. With Some Observations on the Reticulo-Endothelioses. Arch. Dis. Child , **15:** 129–158, 1940.
17. Pentmann, I.: Zur Lehre der Splenomegalie. Frankfurt. Zeitschr. f. Pathol., Wiesb., **18:** 121–151, 1915.
18. Perman, E.: On Haemangiomata in the Spinal Column. Acta Chir. Scandinavica, **61:** 91–105, 1926.
19. Pommer, Gustav: Cited in Luck[14], p. 215.
20. Ribbert, H.: Geschwulstlehre, p. 201. Bonn, Friedrich Cohen, 1914.
21. Schafer, P. W.: Pathology in General Surgery, pp. 26–31, 120. Chicago, University of Chicago Press, 1950.
22. Thomas, Atha: Vascular Tumors of Bone. A Pathological and Clinical Study of Twenty-Seven Cases. Surg., Gynec., and Obstet., **74:** 777–795, 1942.
23. Topfer, D.: Uber ein infiltrierend wachsendes Hamangiom der Haut und multiple Kapillarektasien der Haut und inneren Organe: Zur Kenntnis der Wirbelangiome. Frankfurt. Zeitschr. f. Pathol., **36:** 337–345, 1928.
24. Willis, R. A.: Pathology of Tumors, pp. 700–713. St. Louis, The C. V. Mosby Co., 1948.
25. Weinmann, J. P., and Sicher, Harry: Bone and Bones. Fundamentals of Bone Biology, pp. 400–401. St. Louis, The C. V. Mosby Co., 1947.

# POSSIBLE MECHANISM OF AORTIC RUPTURE IN ORTHOPAEDIC CORRECTION OF RHEUMATOID SPONDYLITIS *

BY PHILIP O. LICHTBLAU, M.D., AND PHILIP D. WILSON, M.D., NEW YORK, N. Y.

*From the Hospital for Special Surgery, New York*

Rheumatoid spondylitis, if allowed to progress, becomes a tragedy, permanently disfiguring and disabling. At this stage the treatment falls within the realm of the orthopaedist. To date, the best treatment of deformity lies in the field of prevention. Swaim states that, for best results, orthopaedic treatment should begin as early as possible, at least within the first three years following the onset, although much can be done up to nine years. However, until the time comes when the disease process itself can be prevented, the orthopaedic surgeon will be confronted with severe deformities which require skillful management in order to obtain even the slightest improvement.

Several articles have appeared in the literature dealing with osteotomy of the spine in Marie-Strümpell arthritis. The condition is a prevalent one and the procedure is being performed, on occasions, at various institutions. The neurological dangers involved are well known. Rupture of the aorta is considered to be a theoretical danger. We feel that the danger is a real one; and if osteotomy is to be performed, the two-stage procedure of La Chapelle, as modified by Herbert, might be indicated.

Review of the literature failed to reveal any reported case of rupture of the aorta. Our respect for this catastrophe emanates from witnessing the treatment of a case at another institution, which this paper will report.

The patient was a thirty-five-year-old white male with severe Marie-Strümpell spondylitis of seven years' duration. He had a marked rounded kyphosis in the thoracolumbar region. He was unable to bring his gaze

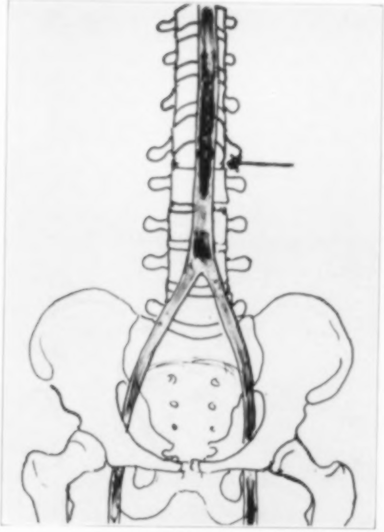


FIG. 1

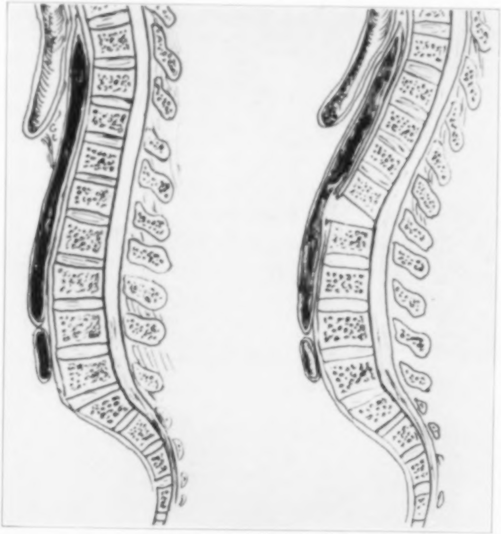


FIG. 2

Diagrammatic sketches of pathological findings noted at autopsy in the case with fatal termination reported herein.

---

* Preliminary paper presented at the New York Academy of Medicine, Section on Orthopaedic Surgery, April 17, 1953.

parallel to the ground, even by flexing his hips and knees. He had had much conservative therapy and several courses of deep x-ray therapy to the thoracolumbar spine, with a total dosage of 2,000 r.

Under general anaesthesia, he was placed supine with a triangular padded wedge beneath the prominence of the kyphos. Light pressure was gradually applied to the shoulders and pelvis for almost one hour. The kyphosis was much improved. He was brought back to the ward and placed on a Bradford frame with a Sayre headhalter and bilateral Buck's traction. He could not tolerate this position and gradually had to be allowed the previous spinal flexion; in but a few days his deformity had recurred completely.

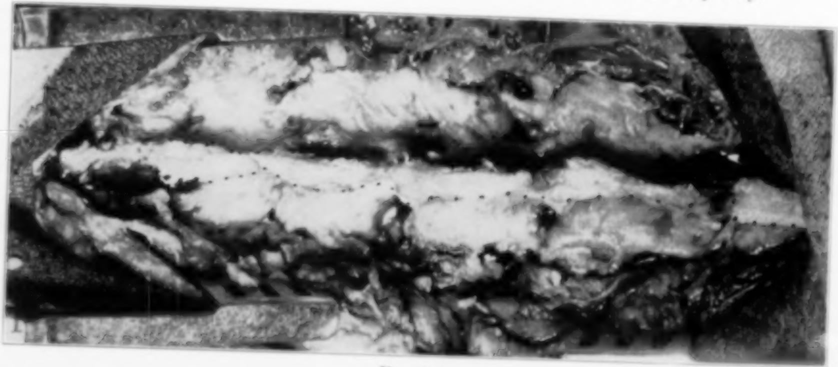


Fig. 3-A

Appearance of the dorsal elements in the lumbar spine. Note the ossification of the interspinous ligaments and ligamentum flavum.

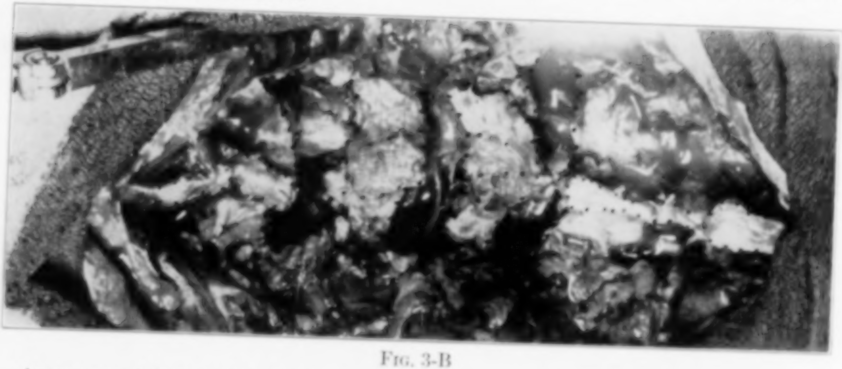


Fig. 3-B

Appearance of the neural arch after complete osteotomy at three lumbar levels—second, third, and fourth lumbar interspaces.

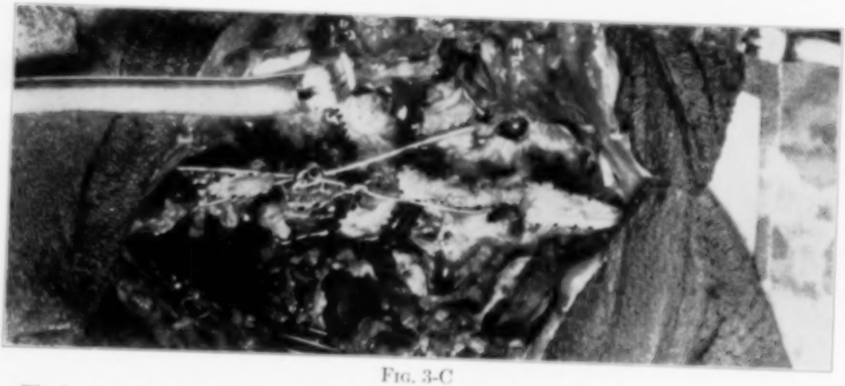


Fig. 3-C

The heavy wire suture is in place. The intervertebral spaces have been decreased, the suture holding the neural arches approximated. The extension of the previously flexed operating table was necessary to help create a lordosis in a previously straight lumbar spine.

Five weeks later the same procedure was attempted. Two audible snaps were produced, extension of the kyphos was gained, and, while a plaster jacket was being applied, the patient was reported to have stopped breathing. The plaster was immediately removed, and a bluish discoloration was noticed in the flanks of the patient. Shock measures were instituted unsuccessfully, and the patient was pronounced dead.

At autopsy there were several interesting and important findings. The aorta in its entirety was not calcified. When it was incised longitudinally, a complete transverse tear was found in its posterior wall,

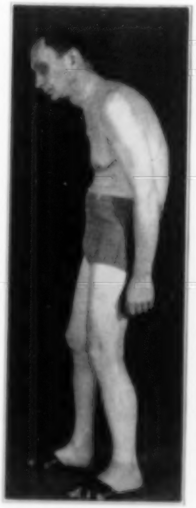


FIG. 4-A

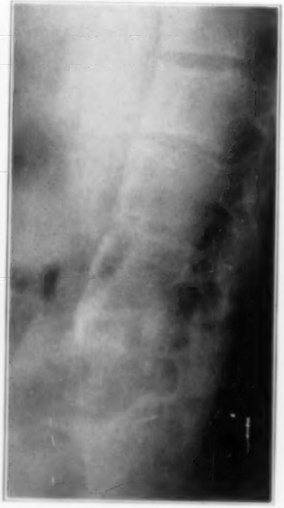


FIG. 4-B

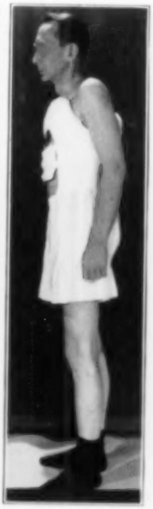


FIG. 4-C

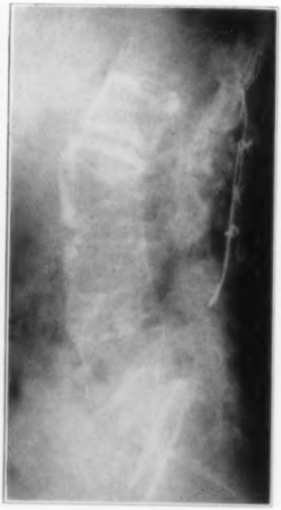


FIG. 4-D

Figs. 4-A and 4-B: Preoperative photograph and roentgenogram.

Fig. 4-C: Postoperative photograph three weeks after spinal osteotomy. Ambulation was begun two weeks after surgery.

Fig. 4-D: Lateral roentgenogram showed the correction gained at the level of the second lumbar vertebra.

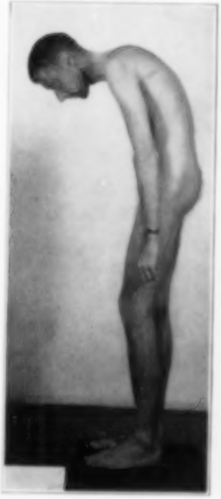


FIG. 5-A

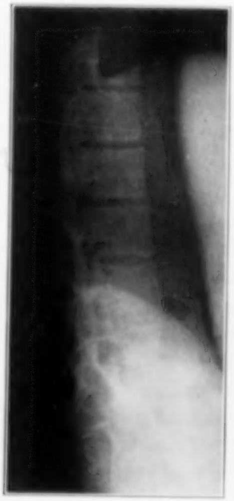


FIG. 5-B

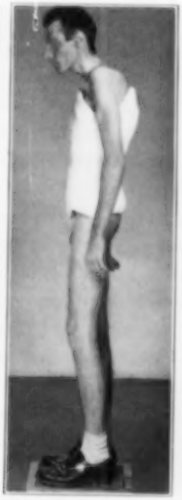


FIG. 5-C

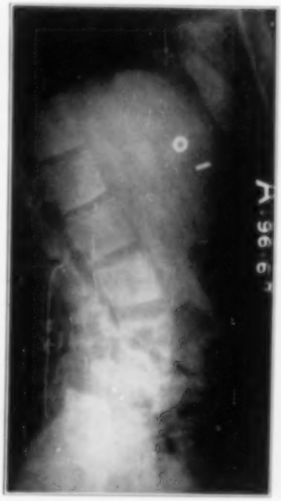


FIG. 5-D

Fig. 5-A: Preoperative photograph.

Fig. 5-B: Preoperative roentgenogram of the lumbar spine. Note the absence of calcification in the intervertebral spaces and along the anterior longitudinal ligament. Note too the loss of normal lumbar lordosis.

Fig. 5-C: Postoperative photograph made two weeks after surgery. A plaster jacket had been applied on the eighth postoperative day. Ambulation was started two days later.

Fig. 5-D: Roentgenogram made three weeks after operation. Note the newly created lumbar lordosis. Most of the correction seems to have been gained at the level of the fourth and fifth lumbar vertebrae.

exactly opposite a gap between the bodies of the first and second lumbar vertebrae which were separated at their anterior margins about three centimeters at the level of the intervening intervertebral disc. The posterior wall of the aorta was firmly adherent to the adjacent anterior longitudinal ligament.

One might expect that a non-calcified aorta would be resilient enough to span a gap of three centimeters—even at the expense of flattening out in the anteroposterior diameter.

Adams, in a recent article, stated that the danger of rupture of the aorta or vena cava was small and he based this belief on the case of a sixty-seven-year-old male who, following osteotomy, was hyperextended at the second lumbar interspace through 90 degrees. Despite advanced atheromatous degeneration with well marked calcification seen roentgenographically in the aorta, the great vessels were undamaged. Postoperative x-rays had shown the calcified aorta markedly flattened anteroposteriorly. It is to be noted that this patient had never had any preoperative x-ray therapy.

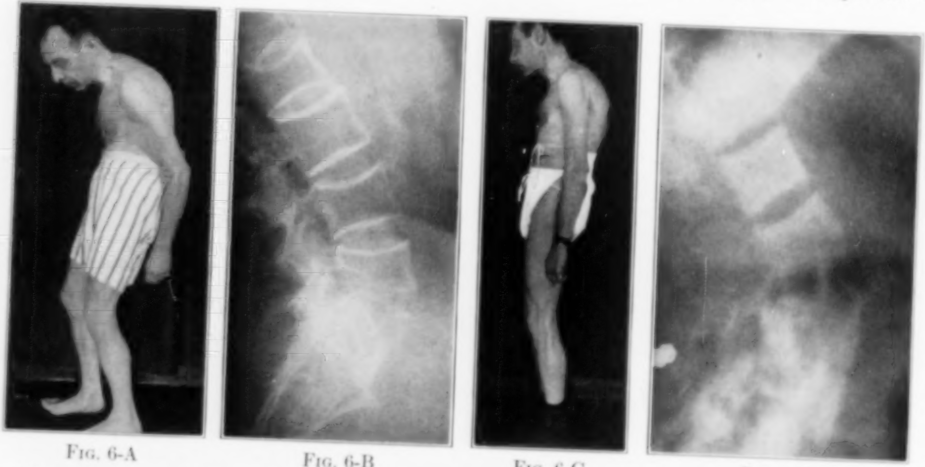


Fig. 6-A Fig. 6-B Fig. 6-C Fig. 6-D

Figs. 6-A and 6-B: Preoperative photograph and roentgenogram.

Figs. 6-C and 6-D: Postoperative photograph and roentgenogram. Osteotomy was performed at the first and second lumbar interspaces. Correction was gained at the second lumbar interspace.

In the case reported in the present article, the total dose of radiation was 2,000 r directed over low thoracic and lumbar poles. We do not believe that a large amount of irradiation passed to the level of the abdominal aorta; but we do suggest that a small amount might possibly have helped produce the adherence that was found at autopsy.

The pathologist did not consider this to be a case of luetic aortitis; the patient's Wasserman reaction was negative on two occasions.

La Chapelle mentioned that gradual or manipulative correction of kyphoses in cases of advanced ankylopoietic spondylo-arthritis had been widely employed for many years with discouraging results.

It is quite true that manipulation of a patient's back, which is the seat of spondylitis, cannot actually be compared to an osteotomy. However, osteotomies probably have and will be performed on individuals similar to the one who was manipulated as reported in this article. If the aorta is adherent to the anterior longitudinal ligament, it is conceivable that, on rupture of the ligament, which is usually calcified and is often ossified, the adjacent aorta, calcified or not, may not be permitted to give, as the vertebrae are separated at the intervertebral disc and rupture may ensue.

We can find no reference indicating that in the pathology of Marie-Strümpell arthritis, the disease process extends from the anterior longitudinal ligament to the aorta. In combing the literature, we could find no observation as to its occurrence or non-occurrence.

Recently, an autopsy was performed on one who had had a long-standing rheumatoid spondylitis; the aorta was not attached any more than is usual to the underlying anterior longitudinal ligament. The disease process itself, in later stages, may, however, involve the anterior longitudinal ligament. It may extend beyond these confines to involve the adjacent aorta. Postmortem observations are rare, as the disease in itself is not fatal, and these patients usually die in the care of a medical man not specifically interested in spondylitis. Thus we are not sure how much adherence is produced between the two structures by the disease process itself. However, we do know that under certain conditions, x-rays cause the formation of fibrous tissue as it is seen in treated cutaneous cancer. We also know that most cases of rheumatoid spondylitis are treated conservatively for years before any question of surgery is entertained. In the conservative management of these cases, x-ray therapy today still plays a dominant role and in many cases may help to produce adherence of the aorta to the anterior longitudinal ligament.

In this regard, it was interesting to review the cases of spinal osteotomy performed at the Hospital for Special Surgery. One-stage osteotomy was performed from the twelfth thoracic vertebra to the second lumbar vertebra in one case, between the twelfth thoracic and the third lumbar vertebrae in the second, and between the second and the fourth lumbar vertebrae in the third case. Thus, vertebrae at several levels were osteotomized in each case, before the flexed position was converted and the bone graft fixed in place. However, of particular interest to us is the fact that only one case had received preoperative radiation therapy; in that case the dosage was low and was given just one week prior to osteotomy. In one patient, the anterior margins of the bodies of the first and second lumbar vertebrae showed roentgenographic evidence of being separated at least 2.5 centimeters after the operative procedure; his course was uneventful and result was satisfactory.

In April 1953, we performed another one-stage osteotomy from the first lumbar vertebra to the fourth lumbar vertebra (Figs. 4-A to 4-D). This patient had received two courses of x-ray therapy four years prior to surgery. However, he had been given a total dosage of only 600 r. It is highly improbable that this small amount of radiation could have produced any significant effect at the depth of the abdominal aorta.

Our most recent osteotomy was performed in August 1953. The patient was a thirty-four-year-old male who had not been able to look straight ahead for six years. He had not received radiation therapy. Following spinal osteotomy, he gained almost 30 centimeters in height and was able to gaze directly forward while standing and walking (Figs. 5-A to 5-D).

It is interesting, that in all our cases, although osteotomies were performed at two or three levels, the correction invariably was gained at the expense of only one interspace opening up anteriorly (Figs. 6-A to 6-D).

In summary, we feel that in cases of rheumatoid spondylitis, large doses of x-ray therapy may be a factor in producing fibrous fixation between the aorta and the underlying anterior longitudinal ligament. A true danger might then exist if following a spinal osteotomy, the anterior longitudinal ligament at any of the upper lumbar levels were transversely torn while a previously flexed spine was extended, without previous regard to freeing the attached, relatively fixed aorta by a two-stage procedure [3].

## REFERENCES

1. Adams, J. C.: Technique, Dangers and Safeguards in Osteotomy of the Spine. J. Bone and Joint Surg., **34-B**: 226–232, May 1952.
2. Adams, J. C.: Personal communication, April 13, 1953.
3. Herbert, J. J.: Vertebral Osteotomy. J. Bone and Joint Surg., **30-A**: 680–689, July 1948.
4. La Chapelle, E. H.: Osteotomy of the Lumbar Spine for Correction of Kyphosis in a Case of Ankylosing Spondyloarthritis. J. Bone and Joint Surg., **28**: 851–858, July 1946.
5. Swaim, L. T.: The Orthopaedic Treatment of Marie-Strümpell Arthritis. J. Bone and Joint Surg., **21**: 983–991, Oct. 1939.

# DEVELOPMENTAL ANOMALY OF THE LATERAL MALLEOLUS SIMULATING FRACTURE

BY R. G. B. BJORNSON, M.D., NEW YORK, N. Y.

*From the Presbyterian Hospital, New York*

Two cases of a rare developmental anomaly of the lateral malleolus, mistakenly diagnosed and treated as cases of recent fractures, are reported.

CASE 1. A sixteen-year-old schoolboy turned his left ankle while playing basketball (March 9, 1954), and shortly thereafter was found to have marked swelling and tenderness about the lateral malleolus. Roentgenograms of the left ankle in frontal, lateral, and oblique projections were made; the lateral showed what was thought to be a fracture line in the lateral malleolus. Treatment was begun accordingly. Eleven weeks later the patient was out of plaster, and his ankle was "asymptomatic". Roentgenograms in the same three projections then showed no evidence of callus formation or other interval change about what had been thought to be the fracture line. No normal epiphyseal synchondroses in the foot or the ankle remained.

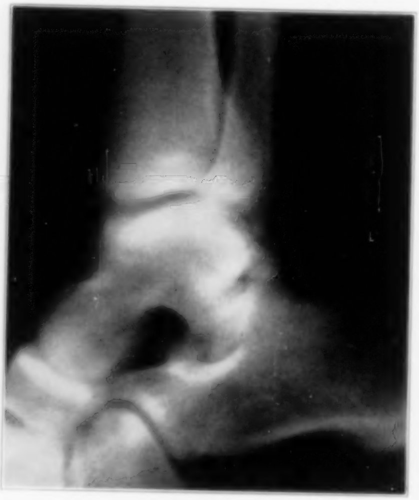


FIG. 1-A

Case 1. Right.
May 26, 1954.

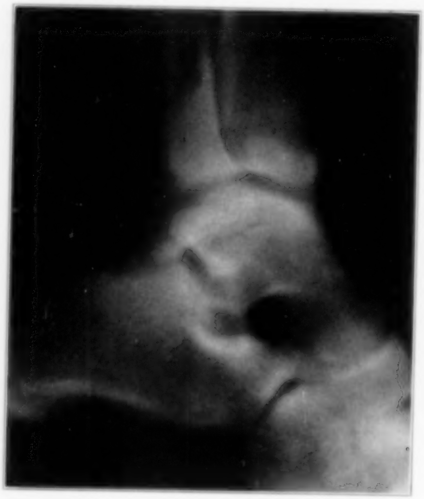


FIG. 1-B

Case 1. Left.
May 26, 1954

Interestingly, this patient had been seen in 1947 at the age of nine years after having turned the same ankle. Roentgenograms had then been made and review of them showed the same oblique line of lesser density to have been present in an unusually large lateral malleolus. A distal fibular epiphyseal synchondrosis was seen in the usual location. No comparison films of the right ankle had been made. Comparison films of the right ankle after the more recent injury showed no evidence of abnormality.

CASE 2. A twelve-year-old schoolboy turned his right ankle while playing at school (March 16, 1954) and a short time later was found to have swelling and tenderness about the lateral malleolus. Roentgenograms were made of both ankles in frontal, lateral, and oblique projections. No abnormality was seen on the left, but on the right the lateral view showed what was thought to be an irregular fracture line through the lateral malleolus. A normal distal fibular epiphyseal synchondrosis was seen. This case was treated as one of lateral malleolar fracture, and eight weeks later the patient was found clinically to have a normal ankle. Roentgenograms then showed no evidence of callus or other interval change about the line first thought to have indicated fracture.

## DISCUSSION

Review of the books which in the main provide us with our bases for judgment regarding normalcy and abnormalcy in the skeleton and, particularly, in the foot and an-

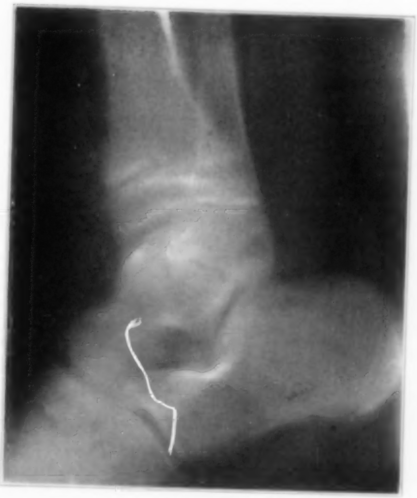


FIG. 2-A

Case 2. Right.
May 19, 1954.

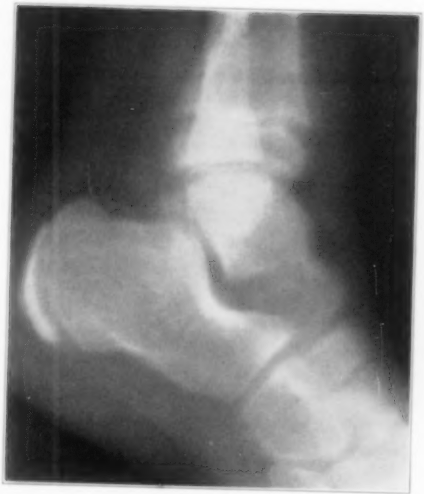


FIG. 2-B

Case 2. Left.
May 19, 1954.

kle [1-4,6-8,10-14] revealed no mention of such a finding as the one reported here. Yet some observers felt that the findings in these patients strongly suggested anomaly and favored that diagnosis—together with, of course, that of ligamentous injury—lack of discovered documentation of such an anomaly notwithstanding. It was pointed out that each affected malleolus was distinctly larger than its unaffected fellow and was somewhat bifid and that the contested oblique (anterosuperior to postero-inferior) line of lesser density was in, or crossed the base of, the stubby anterior limb. In each patient, the bony borders of the line of lesser density were slightly more dense than contiguous bone and showed a waviness similar to that of an epiphyseal synchondrosis.

The possibility that these are old ununited fractures with consequent malleolar deformity is not entirely excluded, though I feel that the findings make it remote.

It seems likely that these are cases of rare persistent secondary centers of ossification occurring in unusually large lateral malleoli and with the synchondroses so directed as to cause an increasing tendency toward bifid malleoli with growth. It is interesting that in the case of the first patient, the bifid malleolus seemed slightly more pronounced on the roentgenograms made in his seventeenth year than on those made in his tenth year. The affected malleolus in the first case was clearly more bifid than was the affected malleolus in the second. The second patient was only twelve years old and had some time for growth left. It is at least possible that the malleolar bifidity in that case may increase. At all events, follow-up films in both patients to perhaps the age of twenty-five or to the time of eventual ossification across these likely synchondroses would be interesting.

Incidentally, there seems no doubt that the findings here are quite different from those with the so-called *os subfibulare* described by Leimbach and thought by him to be a peronaeus tendon sesamoid bone, or perhaps a persistent epiphysis of the processus trochlearis calcanei. The os subfibulare is best shown in the frontal roentgenogram, while the findings described here are recognized only in the lateral roentgenogram.

One cannot know just how the unilateral spongy anomalous bone described by Gruber as articulating with the lateral malleolus would have appeared in a roentgenogram, but his description and the pertinent diagram indicate it to have been posterolateral to the malleolus. Gruber finally termed it an unusual circumscribed ossification of the retinaculum peroneorum superioris—far indeed from what would be reasonable in these two cases.

The question as to whether the bony and ligamentous arrangement in the condition reported here might predispose to lateral ankle instability is raised but not answered. Stress films to demonstrate ligamentous laxity were not made in either of these cases.

Tomograms (Figs. 1-A through 2-B) were made in order to show particularly clearly the affected malleoli and their unaffected fellows. These were made in the medial-to-lateral projection with the foot so placed that the lateral malleolus rested on the table top. The plane of sharp focus chosen was one centimeter above the table top. The result was, of course, that a thin "slice" of lateral malleolus was clearly shown while the rest of the ankle structure was rather effectively blurred.

NOTE: My thanks are due Dr. Alan DeForest Smith, Chief of the Orthopaedic Service; Dr. Harold Jacox, Chief of the Radiologic Service; and Dr. Russell Wigh, Chief of the Central Diagnostic Radiology Section, The Presbyterian Hospital in the City of New York, for their kind permission to publish these cases.

## REFERENCES

1. BRAILSFORD, J. F.: The Radiology of Bones and Joints. Ed. 4. London, J. and A. Churchill, 1948.
2. CAFFEY, J.: Pediatric X-Ray Diagnosis. Ed. 2. Chicago, Year Book Publishers, 1950.
3. EHALT, W.: Unfallchirurgie im Röntgenbilde. Aufl. 2. Wien, Wilhelm Maudrich, 1952.
4. GOLDEN, Ross (Editor): Diagnostic Roentgenology. Vol. 2. Baltimore, Williams and Wilkins Co., 1952.
5. GRUBER, W.: Ueber einen am Malleolus externus articulirenden Knochen. Arch. Pathol. Anat. u. Physiol.f.Klin.Med., **27**: 205–206, 1863.
6. HOHMANN, G.: Fuss und Bein. Aufl. 5. München, J. F. Bergmann, 1951.
7. KOHLER, A., und ZIMMER, E. A.: Grenzen des Normalen und Anfänge des Pathologischen im Röntgenbilde des Skelettes. Aufl. 9. Stuttgart, Georg Thieme, 1953.
8. LEWIN, PHILIP: The Foot and Ankle. Ed. 3. Philadelphia, Lea and Febiger, 1947.
9. LEIMBACH, G.: Akzessorische Fusswurzelknochen. Arch. Orthop. Chir., **38**: 431–448, 1937.
10. MARTI, T.: Die Skelettvarietäten des Fusses. Bern, Hans Huber, 1947.
11. SCHINZ, H. R.; BAENSCH, W. E.; FRIEDL, E.; und UEHLINGER, E.: Lehrbuch der Roentgendiagnostik. Stuttgart, Georg Thieme, 1952.
12. SHANKS, S. C., and KERLEY, P.: A Text-Book of X-Ray Diagnosis. Ed. 2. London, H. K. Lewis and Co., 1950.
13. TROLLE, DYRE: Accessory Bones of the Foot. Copenhagen, Ejnar Munksgaard, 1948.
14. WERTHEMANN, A.: Die Entwicklungsstörungen der Extremitäten. *In* Handbuch der speziellen pathologischen Anatomie und Histologie, IX Band: Bewegungsapparat, 6 Teil of O. Lubarsch, F. Henke, and R. Rössle. Berlin, Springer-Verlag, 1952.

# OSTEOCHONDRODYSTROPHY AS A RESULT OF OR IN RELATION TO PSEUDO-HYPOPARATHYROIDISM

BY GEORGE J. GARCEAU, M.D., AND WALLACE E. MILLER, M.D., INDIANAPOLIS, INDIANA

*From the Department of Orthopaedic Surgery of the James Whitcomb Riley Hospital, Indiana University School of Medicine, Indianapolis*

During the past ten to fifteen years there has been a number of reported cases of pseudo-hypoparathyroidism, or as it is sometimes called "Seabright Bantam syndrome". Some of these cases are associated with non-characteristic changes as is true of this case now being reported. However, most of the reported cases present symptoms of a condition which might be expected in the absence of the normal parathyroid output of hormone.[1-12] The term "Seabright Bantam syndrome" evolved from experiments reported by Morgan in 1915 and 1917. The Seabright Bantam is a species of fowl in which the male shows female plumage and comb, although normal testes have been demonstrated; this species has been considered a classic example of end-organ refractoriness to a normal amount of circulating hormone. Therefore, the name has been used to indicate a refractory end-organ producing a condition resembling a glandular deficiency. Review of Morgan's original papers on the Seabright Bantam leaves a doubt as to whether this bird represents a true example of end-organ refractoriness. It was shown that following castration the male Bantam did develop normal male plumage and comb, suggesting the presence of an endocrine inhibiting action rather than a true end-organ refractoriness. Seabright Bantam syndrome would be a general descriptive name for a syndrome involving other than the parathyroid hormone; however, it has been popularly taken up to describe just the latter deficiency.

The physical characteristics of a patient with this type of disorder are short stature, round face, short thick neck, and hands that are short, stubby, and fat. The fingers are short and occasionally rounded due to early closure of the epiphyses. There is a shortness of the long bones in relation to the trunk. Soft-tissue calcification is present. To justify a diagnosis it is felt that the patient should have chronic tetany (a low level of serum calcium and an elevated level of serum inorganic phosphorus). Normal renal function should be present.

In the most recent article by Albright and his associates, the general impression of the nature of pseudo-hypoparathyroidism, as a whole, is a genetic disorder. The disease syndrome expresses itself not only through a disturbance of the hormone function of the parathyroid at the end-organ but also in a form of dyschondroplasia and a tendency toward the formation of soft-tissue calcification. Since the same changes in the blood studies are present in idiopathic hypoparathyroidism with an absence of dyschondroplasia and of ectopic ossification, it is considered that these changes are not secondary to the disordered blood chemistry resulting from the end-organ resistance. It was noted by these same authors that myositis ossificans progressiva is closely related to pseudo-hypoparathyroidism, since it has both the ectopic ossification and the tendency to dyschondroplasia but lacks the insensitivity to the parathyroid hormone. In the early reports, less attention was given to the skeletal abnormalities than in the more recently reported cases.

The primary action of the parathyroid hormone is to diminish the reabsorption of phosphate in the renal tubules. Parathyroid extract causes decalcification of bone. A. T. 10 (dihydrotachysterol) also produces demineralization of bone. In pseudo-hypoparathyroidism, there is a failure of response to normal parathyroid secretion rather than a primary insufficiency of the parathyroid glands. It has been the observation of Albright and

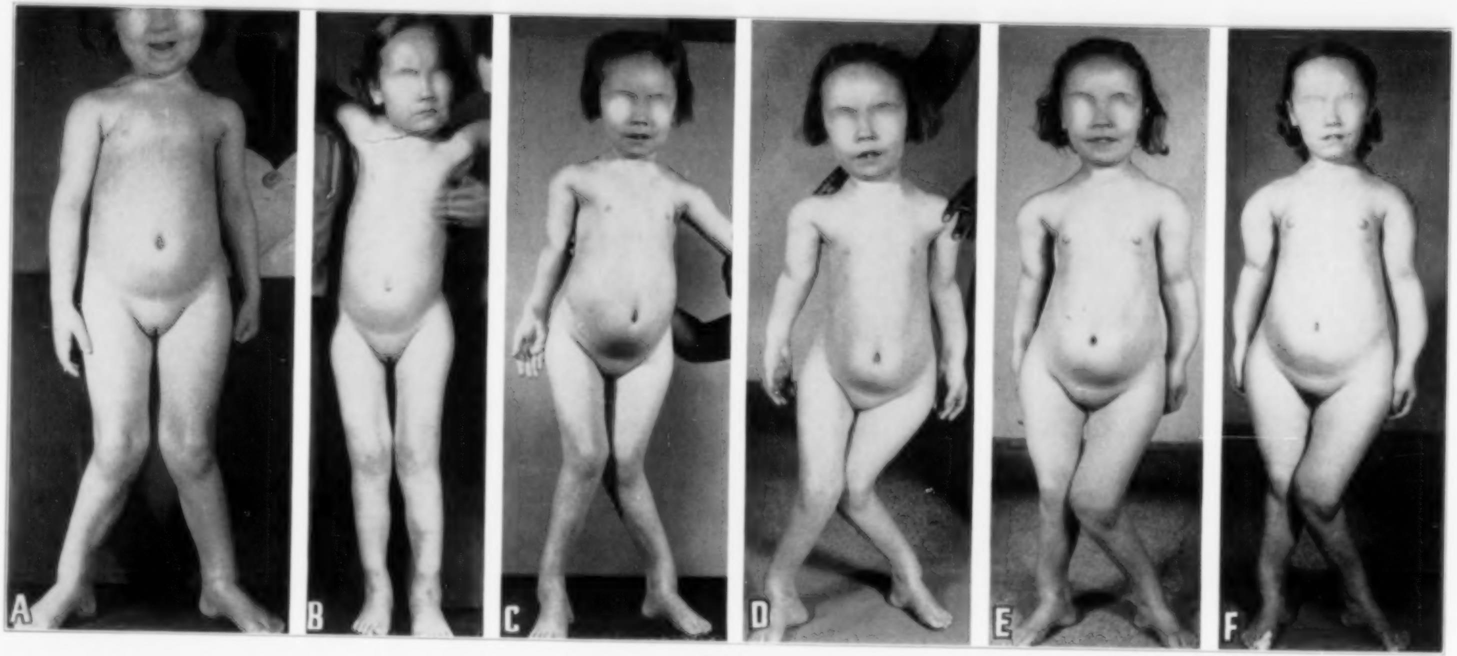


Fig. 1

Figs. 1, *A* through *F*: Photographs of the patient made over a period of eleven years: (*A*) 1944, at age of five and one-half years; (*B*) 1946, one year after femoral and tibial osteotomies; (*C*) November 1949, blood chemistry study of patient was begun; (*D*) April 1951, administration of dihydrotachysterol (A. T. 10) was started; (*E*) April 1952, blood chemistry was nearly normal; (*F*) January 1953, progress of deformities under control.

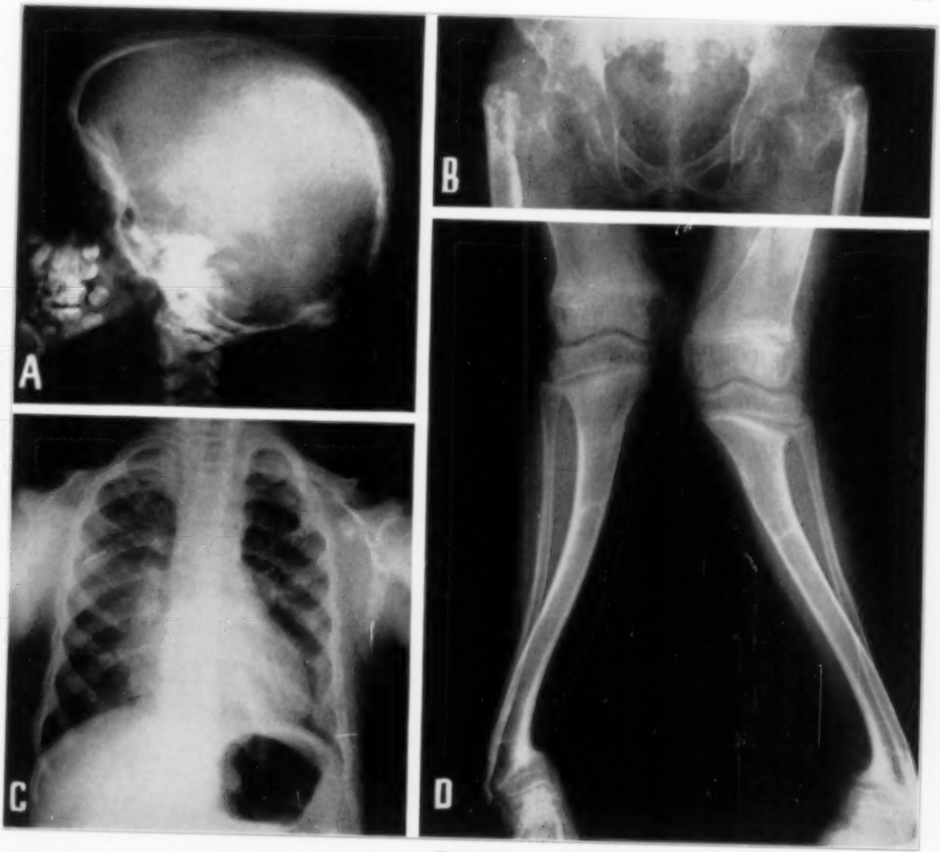


FIG. 2

Figs. 2, *A* through *D*: (*A*) Lateral roentgenogram of skull in 1949; (*B*) Anteroposterior roentgenogram of pelvis in 1949, showing the deformities of the femoral head and neck bilaterally with the changes of advanced osteochondrodystrophy; (*C*) Chest roentgenogram made in 1949, shows the narrowing of the chest and osteochondrodystrophic changes of the shoulder regions; (*D*) Anteroposterior roentgenogram made of both lower extremities in 1949.

his associates[1] that patients with this syndrome respond more slowly to A. T. 10 than do patients with true hypoparathyroidism. Also it has been noted by the same authors that Vitamin D and A. T. 10 have a double effect; they increase the absorption of calcium from the gastro-intestinal tract and at the same time increase the excretion of phosphate by the kidney. However, the proportions of these effects, one to the other, differ with the two agents. The ratio of phosphate-excreting response to the calcium-absorption response is greater with A. T. 10 than with Vitamin D. The treatment varies inasmuch as some patients respond to high-calcium, low-phosphate acid-ash diets and others respond to Vitamin D and A. T. 10.

The Ellsworth-Howard test is considered to be a specific test to rule out hypoparathyroidism. This test is performed on a fasting patient. Parathyroid extract is given intravenously (two milliliters or 200 units). The total excretion of urinary phosphate is checked hourly for three hours before and three hours after the injection. The test in a normal control shows phosphate diuresis. If the patient has a pseudo-hypoparathyroidism there is no diuresis.

The condition described in the following case follows much the same pattern as that described in the Seabright Bantam syndrome with additional changes of bone

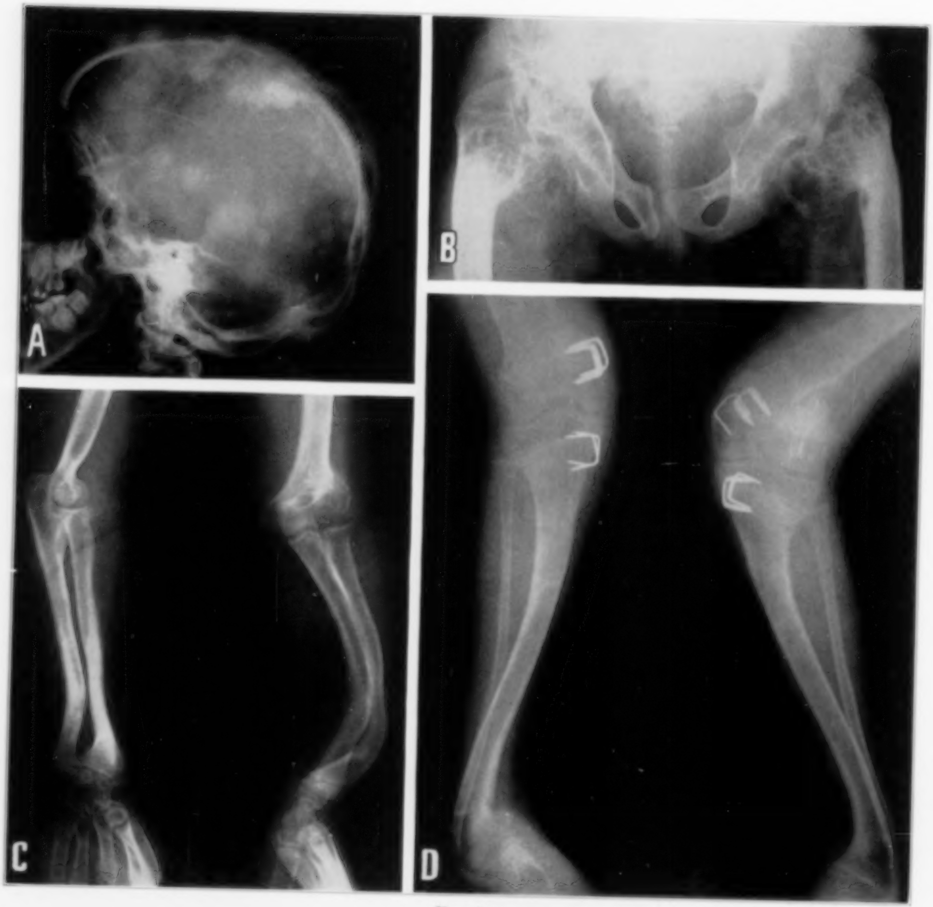


FIG. 3

Fig. 3, *A* through *D*, roentgenograms made in 1951: (*A*) Lateral roentgenogram of the skull shows multiple calcific densities; (*B*) Anteroposterior roentgenogram of the pelvis, showing no progression of the previously noted deformities but a maturation of bone in the deformed state; (*C*) Anteroposterior and lateral roentgenograms of the right forearm, showing the dystrophic changes present; (*D*) Anteroposterior roentgenograms of both lower extremities, one month after the stapling of the epiphyses and one month after the epiphysiodeses.

which are difficult to explain unless one also assumes the presence of an osteochondrodystrophy.

## CASE REPORT

*November 1944 (First Admission)*

The patient, a girl, was first seen in November 1944, at the age of five and one-half years. Deformities of the hips, knees, and ankles had developed during the preceding eight months, and difficulty in walking was the chief complaint (Fig. 1, *A*). Otherwise, the past history was non-contributory and the family history indicated no tendency toward deformities. The patient had been receiving twenty-four drops daily of cod-liver-oil concentrate. At the time of the first visit, the main physical findings were an enlarged head, mottled and crooked teeth, severe genu valgum, and a flaring and irregularity of the epiphyses. It was considered that the condition most resembled a dyschondroplasia. On the basis of this diagnosis, treatment by a series of osteotomies was begun. Bilateral tibial osteotomies were done in December 1944, and supracondylar femoral osteotomies were done in October 1945 (Fig. 1, *B*). During the next three years, the patient was treated with braces in an attempt to control the deformities.

*May 1949 and November 1949 (Second and Third Admissions)*

The problem of diagnosis and treatment was again brought to the forefront in May 1949, when the

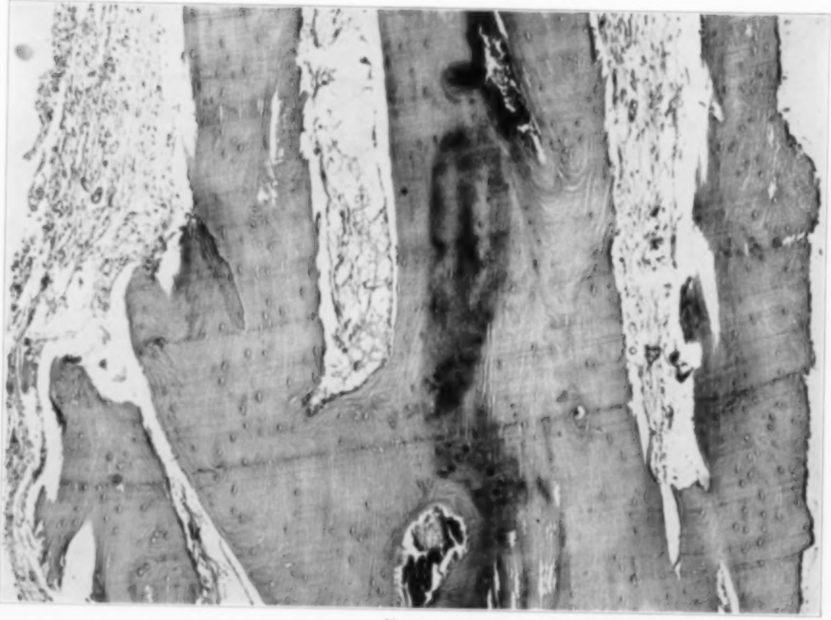


FIG. 4

Photomicrograph (low power view) of specimen of bone obtained by biopsy in 1950. The appearance of the fragments of cortical bone is compatible with osteomalacia, although this condition was not present.

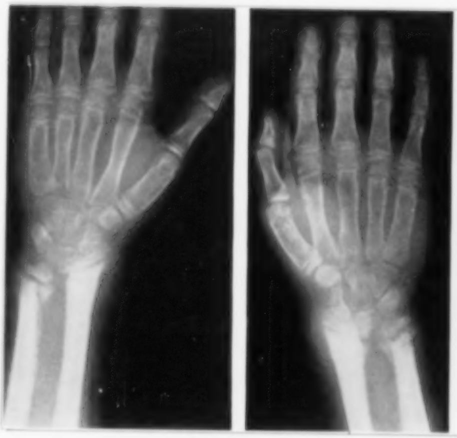


FIG. 5-A

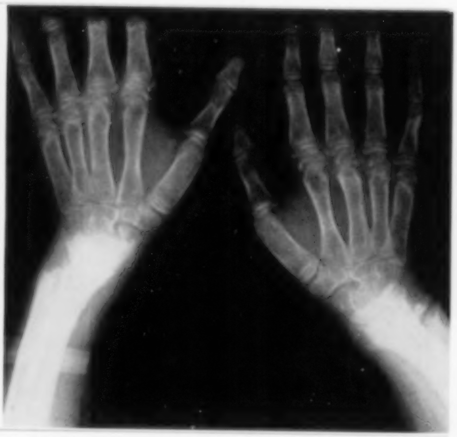


FIG. 5-B

Fig. 5-A: Roentgenograms of the hands made in November 1946.
Fig. 5-B: Roentgenogram of the hands made in May 1949.

patient was admitted in mild tetany. The main findings were laryngeal stridor, carpopedal spasm, vomiting, a positive Chvostek's sign, and general acute illness. The mother stated that there had been evidences of laryngeal stridor beginning four months prior to this admission. The tetany was relieved by the administration of calcium gluconate intravenously, and a high-calcium diet was then started in addition to oleum percomorphum. Laboratory studies at this time revealed: serum calcium, 4.6 milligrams per 100 milliliters; serum phosphorus, 6.0 milligrams per 100 milliliters; serum alkaline phosphatase, 77 King-Armstrong units; urine calcium, 5.3 milligrams per twenty-four hours; and the Sulkowitch test showed negative results. Results of laboratory studies a month after the beginning of treatment revealed: serum calcium, 8.0 milligrams per 100 milliliters; serum phosphorus, 6.0 milligrams per 100 milliliters; and serum alkaline phosphatase, 71 King-Armstrong units.

TABLE I

SEROLOGY

Total Protein

| | | *Grams per 100 Milliliters* |
|---|---|---|
| Normal in children: | | 6–8 |
| Patient: | | |
| October 22, 1949 | Total protein | 6.24 |
| | Albumin | 4.61 |
| | Globulin | 1.63 |
| April 20, 1950 | Total protein | 7.34 |
| | Albumin | 5.08 |
| | Globulin | 2.26 |
| January 1, 1951 | Total protein | 7.20 |
| | Albumin | 4.99 |
| | Globulin | 2.21 |
| April 2, 1951 | Total protein | 7.20 |
| | Albumin | 4.70 |
| | Globulin | 2.50 |
| May 14, 1951 | Total protein | 7.20 |
| | Albumin | 4.89 |
| | Globulin | 2.31 |
| December 5, 1951 | Total protein | 7.80 |
| | Albumin | 5.37 |
| | Globulin | 2.43 |

Serum Bilirubin

| | *Time in Minutes* | *Milligrams per 100Milliliters* |
|---|---|---|
| Normal: | | 0.05–0.50 |
| Patient: | | |
| April 20, 1950 | 1 | 0.2 |
| | 5 | 0.2 |
| May 14, 1951 | 1 | 0.2 |
| | *Total* | 0.5 |
| | *Indirect* | 0.3 |

Serum Potassium

| | *Milligrams per 100 Milliliters* |
|---|---|
| Normal: | 18–22 |
| Patient: | |
| April 21, 1950 | 19 |

Prothrombin Time

| | *Conversion Time* |
|---|---|
| Normal: | 10–15 seconds |
| Patient: | 13.0 seconds |

Cephalin-Cholesterol Flocculation Test

| | |
|---|---|
| April 20, 1950 | Negative |
| April 5, 1951 | Negative |

Serum Chloride

| | *Milligrams per 100 Milliliters* |
|---|---|
| Normal: | 370 |
| Patient: | |
| April 24, 1950 | 333 |

Serum Sodium

| | *Milliequivalents per Liter* |
|---|---|
| Normal: | 137–143 |
| Patient: | |
| April 21, 1950 | 139.1 |
| April 4, 1951 | 149.6 |

Non-Protein Nitrogen

| | *Milligrams per 100 Milliliters* |
|---|---|
| Normal: | 25–40 |
| Patient: | |
| May 13, 1949 | 23 |
| October 25, 1949 | 26 |
| March 16, 1950 | 25 |
| April 2, 1951 | 37 |
| May 15, 1951 | 37 |

Blood-Urea Nitrogen

| | *Milligrams per 100 Milliliters* |
|---|---|
| Normal: | 10–20 |
| Patient: | |
| May 13, 1949 | 13.2 |
| March 16, 1950 | 12.7 |
| April 4, 1951 | 13.7 |

Carbon Dioxide Combining Power

| | *Volumes per 100 Milliliters* | *Milliequivalents per Liter* |
|---|---|---|
| Normal in children: | 50–70 | 22–31 |
| Patient: | | |
| May 12, 1949 | 68 | 31 |
| April 24, 1950 | 61 | 27 |

TABLE II-A

URINALYSIS

Ellsworth-Howard Test *

| | Time | Total Volume of Urine *(Milligrams per 100 Milliliters)* | Inorganic Phosphorus *(Milligrams per 100 Milliliters)* | Inorganic Phosphorus *(Milligrams per Hour)* |
|---|---|---|---|---|
| Normal Control: | | | | |
| *Before injection* | | | | |
| | 7:00 A.M. | 45 | .712 | 32.04 |
| | 8:00 A.M. | 262 | .166 | 43.49 |
| | 9:00 A.M. | 325 | .098 | 31.85 |
| *After injection of 2 milliliters of parathyroid extract (200 units)* | | | | |
| | 11:00 A.M. | 295 | .292 | 86.14 |
| | 12:00 A.M. | 31 | 1.900 | 58.90 |
| | 1:00 P.M. | 39 | .924 | 37.04 |
| Patient: | | | | |
| *Before injection* | | | | |
| | 7:00 A.M. | 82 | .356 | 29.19 |
| | 8:00 A.M. | 75 | .436 | 32.80 |
| | 9:00 A.M. | 79 | .254 | 20.07 |
| *After injection of 2 milliliters of parathyroid extract (200 units)* | | | | |
| | 10:45 A.M. | 73 | .234 | 17.08 |
| | 11:45 A.M. | 24 | .924 | 22.18 |
| | 12:45 P.M. | 108 | .228 | 24.62 |

* In explanation of the above test, it can be noted that there is no phosphate diuresis present in the patient, whereas, there appears to be the normal response of phosphate diuresis in the control following injection of parathyroid extract. It has been concluded with this test, as in previous tests, that the patient shows no response to the intravenous injections of parathyroid extract which is typical of patients with pseudo-hypoparathyroidism.

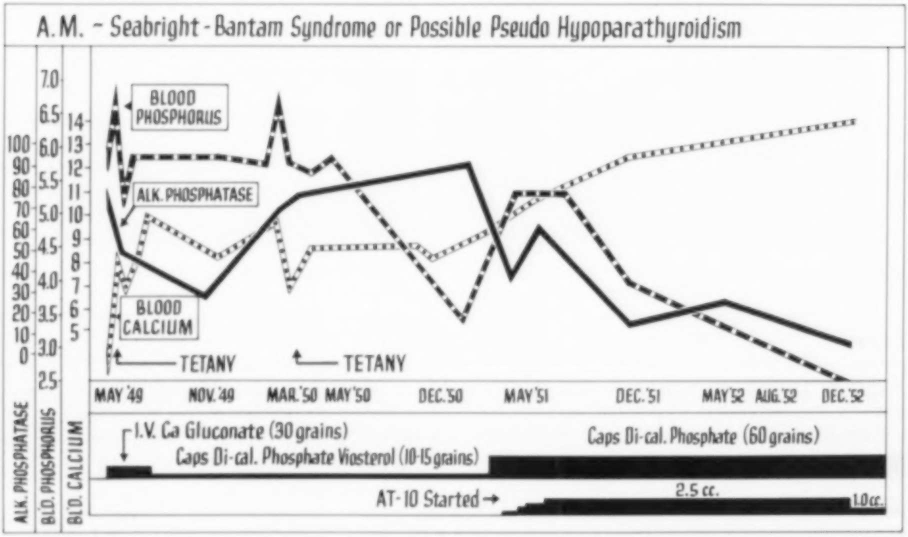


CHART I

### TABLE II-B

### URINALYSIS

Mosenthal Test

April 5, 1951

| Specimen | Time Specimen Collected | Volume of Urine (*Milliliters*) | Specific Gravity |
|---|---|---|---|
| First | 8:00 A.M. to 10:00 A.M. | 170 | 1.006 |
| Second | 12:00 A.M. | 95 | 1.009 |
| Third | 2:00 P.M. | 298 | 1.001 |
| Fourth | 4:00 P.M. | 124 | 1.008 |
| Fifth | 6:00 P.M. | 70 | 1.015 |
| Sixth | 8:00 P.M. | 89 | 1.005 |
| Seventh | 8:00 P.M. to 8:00 A.M. | 110 | 1.025 |

Urine Specific Gravity Tests

Twenty-two tests for the specific gravity of urine have been done over the past seven years; the average was 1.018. In the same number of tests, there have been no casts and no albumin; the pH has been within normal limits.

Glucose-Tolerance Test

December 29, 1952

| Specimen | Time Elapsed before Test | Blood Sugar (*Milligrams per 100 Milliliters*) | Urine Sugar (*Grams per 100 Milliliters*) |
|---|---|---|---|
| *After fasting* | 12 hours | 90 | Negative |
| *After administration of 100 grams of dextrose* | | | |
| First | 30 minutes | 165 | 0.40 |
| Second | 1 hour | 174 | 0.45 |
| Third | 2 hours | 155 | 0.50 |
| Fourth | 3 hours | 118 | 2.50 |

Phenolsulphophthalein Test

| | Time after Injection (*Minutes*) | Excretion of Phenolsulphophthalein (*Per cent*) |
|---|---|---|
| December 30, 1952 | | |
| | 15 | 42 |
| | 30 | 26 |
| Total | 30 | 68 |

Blood-Urea Clearance

| | *Per cent* |
|---|---|
| Normal: | 80–120 |
| Patient: | |
| May 13, 1949 | 119 |
| March 16, 1950 | 48 |

Urea Index

| | |
|---|---|
| Normal: | 54 |
| Patient: | |
| May 13, 1949 | 57 |
| March 16, 1950 | 51 |

Bromsulphalein Test

| | |
|---|---|
| Normal: | No dye after 45 minutes |
| Patient: | |
| April 20, 1953 | Negative after 45 minutes |

$$\text{Urea index} = \frac{\text{BUN}}{\text{NPN}} \times 100$$

No further diagnosis was made at the time of this admission or at re-admission six months later in November, when the child was seen for an incomplete fracture of the femur. It was felt that the abnormal pattern in the blood tests was more related to the osteochondrodystrophy. At the time of the first visit in November 1944, it had been noted that the child had been receiving an adequate amount of cod-liver-oil concentrate (twenty-four drops daily) and this had been continued. At the time of this last admission (November 1949) and following the episode of tetany in May, eight drops of oleum percomorphum daily, calcium gluconate tablets (two grams), and a high-calcium and low-phosphate acid-ash diet were prescribed.

*March 1950 (Fourth Admission)*

The patient was again admitted in March 1950 with an impending tetany suggested by excitability, laryngospasm in association with nervousness, mild carpopedal spasm, a positive Chvostek's sign, and hyperactive tendon reflexes. The patient was again relieved of the tetany shortly after admission, and it was decided that extensive investigative work should be done at this time.

The blood studies on admission revealed a calcium level of 9.7 milligrams per 100 milliliters, a phosphorus level of 5.7 milligrams per 100 milliliters, and an alkaline-phosphatase level of 55 King-Armstrong units per 100 milliliters.

The urinary studies indicated a normal calcium and phosphate output; stool examination for calcium was normal; and the total protein and the albumin-globulin ratio were normal. Results of the urea clearance and Mosenthal tests were normal, indicating that we were not dealing with kidney dysfunction. There were normal results also in the bromsulphalein test, the prothrombin time and serum bilirubin were normal; and the cephalin-cholesterol flocculation tests were negative. Further blood studies indicated a normal carbon dioxide combining power and normal serum levels for potassium, sodium, and chloride.

An electrocardiogram showed a prolonged Q–T interval with the prolongation mainly in the S–T segment, as is found in cases of calcium deficiency. A roentgenogram of the teeth at this time showed a considerable retardation of the eruptive processes. There was a minimum of absorption of deciduous teeth. The general roentgenographic and clinical appearance of the child was considerably changed.

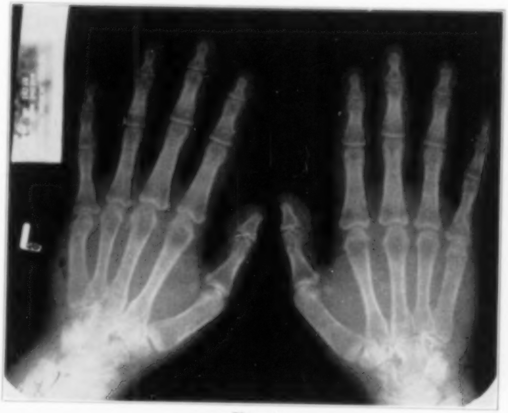


Fig. 6

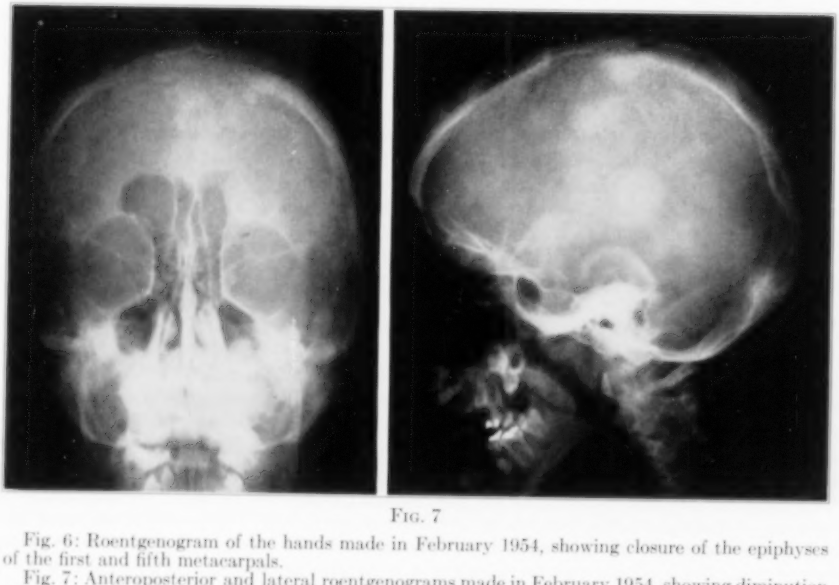


Fig. 7

Fig. 6: Roentgenogram of the hands made in February 1954, showing closure of the epiphyses of the first and fifth metacarpals.

Fig. 7: Anteroposterior and lateral roentgenograms made in February 1954, showing diminution of the areas of increased density of the skull seen in earlier roentgenograms.

All of the previously minor deformities were now much more exaggerated and grotesque. The head was enlarged, the roentgenograms showing a marked thickening of the calvarium which appeared to arise chiefly from the widening of the diploic space and an increase in the width of the outer table. In relation to the rest of the body, the chest appeared dwarfed, and the deformity of the extremities had increased. The roentgenograms again showed that the deformities seemed to be a result of disorganization of the metaphyses at the epiphyseal line. The ribs showed cystic changes and disorganization at the cartilaginous junction. The spine, although osteoporotic, did not show changes. The clinical and x-ray departments again decided that the condition was an osteochondrodystrophy which seemed to most closely resemble that of Morquio's disease.

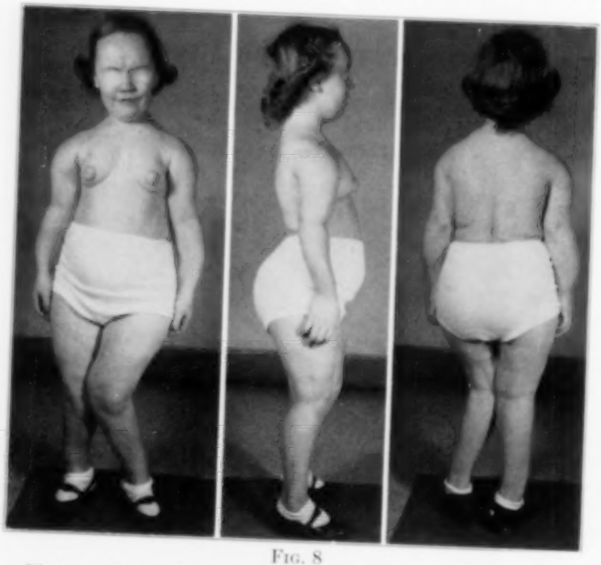


FIG. 8

Photographs made of patient in February 1954, showing the clinical improvement.

A bone biopsy was done next; this revealed cortical bone which had the appearance of, but was not diagnostic of, that found with osteomalacia. It was assumed from the normal values obtained in a series of tests that the patient had no abnormality of the blood-glucose level, had no renal dysfunction, had normal liver function, and was not suffering from rickets (either renal rickets or the so-called Vitamin-D resistant rickets). It was concluded at this time that the clinical aspects of the case suggested one of two conditions,—hypoparathyroidism or pseudo-hypoparathyroidism. Results of the Ellsworth-Howard test showed that there was a resistance to parathyroid extract (Table II-A). Since the parathormone injection did not produce a phosphate diuresis when the patient was tested, the possibility that the patient had hypoparathyroidism was eliminated, leaving the Seabright Bantam syndrome as the only possible diagnosis.

For the next year (March 1950 to May 1951), the patient was continued on medication of oleum percomorphum (twenty drops daily) and dicalcium phosphate with viosterol (one gram); there was evidence of a slow progression of deformities but no further evidence of tetany (Fig. 3).

*May 1951 (Fifth Admission)*

The continued high alkaline-phosphatase level, the unchanging abnormal gait caused by the deformities, and the possibility that A. T. 10 might be effective as additional medication in treatment brought this child's case again to our attention in May 1951. At this time, stapling of the medial femoral and tibial epiphyses and epiphysiodesis of the distal fibular epiphyses were carried out bilaterally (Fig. 3, *D*). For the next eighteen months (until November 1952), a dosage of two and one-half milliliters of A. T. 10 was given daily with improvement both in the deformities and in the blood studies, as can be noted in the photographs (Fig. 1, *E* and *F*) and on the chart showing the changes in the serum calcium, phosphorus, and alkaline phosphatase (Chart I).

*December 1952 (Sixth Admission)*

By December 1952, it appeared that the blood serum levels and the changes noted on roentgenographic examination warranted diminishing the dosage of A. T. 10 to one milliliter daily, which she received until February 1953 in addition to Vitamin D and a high-calcium diet. (In February the dosage of A. T. 10 was increased to 1.3 milliliters daily and has been satisfactorily continued to the present time, although there is laboratory evidence recently that it may be necessary to increase this amount eventually.) A roentgenogram of the skull showed the beginning of circumscribed areas of apparent calcification, and there were multiple calcific densities in the region of the left kidney parenchyma. Urinary tests continued to yield normal values. The evidence of demineralization continues to be present to some extent in the roentgenograms of the long bones, but the progress of the deformities has been controlled. The current problem under consideration is whether the present treatment may be discontinued or modified as the child reaches a more mature stage of bone growth.

## SUMMARY

One new case of pseudo-hypoparathyroidism with severe dyschondroplasia is reported with attention being called to the skeletal abnormalities in particular.

## REFERENCES

1. ALBRIGHT, FULLER; BURNETT, C. H.; SMITH, P. H.; and PARSON, WILLIAM: Pseudo-Hypoparathyroidism —An Example of Seabright-Bantam Syndrome. Endocrinology, **30**: 922–932, 1942.

2. Alexander, S. B., and Tucker, H. St. George, Jr.: Pseudohypoparathyroidism. Report of a Case with Late Manifestations. J. Clin. Endocrinol., **9**: 862–873, 1949.
3. Bakwin, H.; Gorman, W. F.; and Ziegra, S. R.: Pseudohypoparathyroid Tetany. J. Pediat., **36**: 567–576, 1950.
4. Berardinelli, W.: Pseudo-Hypoparathyroidism with Decreased Glucose Tolerance and Diabetes Insipidus. Acta Endocrinol., **7**: 7–16, 1951.
5. Bishop, P. M. F., and DeMowbray, R. R.: Pseudo-hypoparathyroidism. Proc. Roy. Soc. Med., **44**: 952–954, 1951.
6. Ellsworth, Read, and Howard, J. E.: Studies on the Physiology of the Parathyroid Glands. VII. Some Responses of Normal Human Kidneys and Blood to Intravenous Parathyroid Extract. Bull. Johns Hopkins Hosp., **55**: 296–308, 1934.
7. Elrick, Harold; Albright, Fuller; Bartter, F. C.; Forbes, A. P.; and Reeves, J. D.: Further Studies on Pseudo-Hypoparathyroidism: Report of Four New Cases. Acta Endocrinol., **5**: 199–225, 1950.
8. Moehlig, R. C., and Gerisch, R. A.: Pseudohypoparathyroidism with Decreased Glucose Tolerance. Report of a Case. J. Clin. Endocrinol., **10**: 1609–1615, 1950.
9. Morgan, T. H.: Demonstration of the appearance after castration of cock-feathering in a hen-feathered cockerel. Proc. Soc. Exper. Biol. and Med., **13**: 31–32, 1915.
10. Morgan, T. H.: Demonstration of the effects of castration on Seabright cockerels. Proc. Soc. Exper. Biol. and Med., **15**: 3–4, 1917.
11. Peterman, M. G., and Garvey, J. L.: Pseudohypoparathyroidism. Case Report. Pediatrics, **4**: 790–797, 1949.
12. Sprague, R. G.; Haines, S. F.; and Power, M. H.: Metabolic Effects of Parathyroid Hormone, Dihydrotachysterol, and Calciferol in a Case of Pseudohypoparathyroidism. J. Lab. and Clin. Med., **30**: 363–364, 1945.

# OPERATIVE TREATMENT OF OSTEOCHONDRITIS OF THE TIBIAL TUBERCLE *

BY J. E. M. THOMSON, M.D., LINCOLN, NEBRASKA

*From the Lincoln Orthopaedic Center, Lincoln*

Prolonged and repeated periods of immobilization, local pain, withdrawal from athletics and the more strenuous social activities of young people, and, occasionally, an unsightly knob on the front of the leg just below the knee may prove too great a test of patience for parents and youngster alike. The youth may beg to be relieved of his disability by measures more definitive and final, and in the shortest possible time. If the patient is a girl and of the hypersensitive type, she may soon experience some interference with her emotional development. Two to four months in a circular ankle-to-groin plaster-molded splint has been the conventional treatment; sometimes the splintage must be bilateral (ten of thirty-one cases or 33.3 per cent); sometimes this course has to be repeated before Nature can repair the partially avulsed epiphyseal elements in the extensor mechanism.

For the past thirty years, the author has felt that repeated immobilization of the knee or knees was futile; on the other hand, surgery is indicated only if symptoms recur following a properly conducted period of plaster-of-Paris immobilization.

TABLE I

Operative Treatment of Painful Tubercle *

| Type of Operation | Number of Cases | Knees | Fusion | Symptoms | Full Activities | Reinjury | Subsequent Enlargement of the Tubercle |
|---|---|---|---|---|---|---|---|
| Drilling the tubercle. | 4 | 4 | 4 | 0 | 4 | (5 years later) | 4 |
| Drilling the tubercle plus removal of loose fragments. | 4 | 6 | 6 | 0 | 6 | 0 | Some |
| Autogenous-bone pegs inserted; loose fragments removed. | 3 | 3 | 3 | 0 | 3 | 0 | Some had marked enlargement |
| Subcortical excision of tubercle and impaction. | 7 | 10 | 10 | 0 | 10 | 0 | Occasional |
| Complete subperiosteal excision of tubercle. | 14 (1 case of drilling reoperated upon) | 18 | | 1 (17 symptom-free) | 18 | 0 | None |

* The series—31 patients; males 26, females 5.

Period of observation: 2 to 20 years; average per patient 8 years. Average period in hospital—less than one week.

Average age: 13.9 years. Knees: right 8, left 13, bilateral 10.

This report is presented as a record of a series of cases of osteochondritis of the tibia in which there was recurrence after thorough conservative treatment and in which operative measures were then employed. The report reflects the evolution of the author's operative treatment of the condition.

The surgical procedures used consisted in (1) multiple drilling of the tubercle—four cases (Table I), (2) removal of loose fragments followed by multiple drillings—four

---

* Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Los Angeles, California, February 1, 1955.

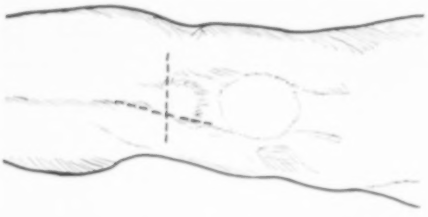


FIG. 1

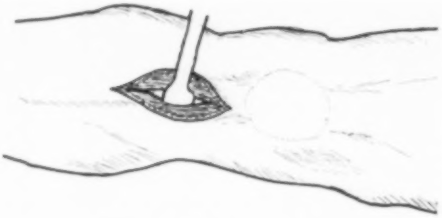


FIG. 2

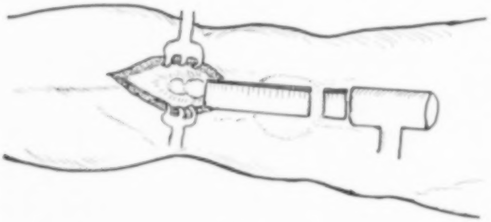


FIG. 3

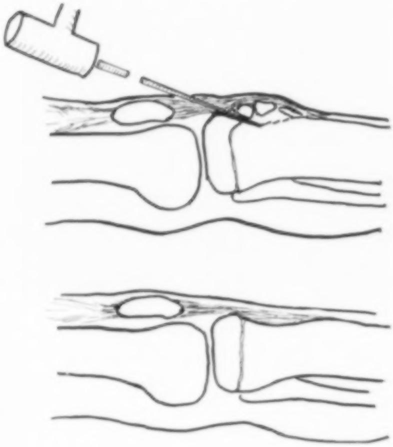


FIG. 4

Fig. 1: The incision may be transverse; usually a medial longitudinal incision two and one-half inches long is used.

Fig. 2: The patellar tendon is split longitudinally and subperiosteally dissected from the enlarged tubercle with a periosteum elevator.

Fig. 3: After reflecting the patellar tendon laterally the entire prominence of the tubercle is removed.

Fig. 4: (Upper drawing.) Lateral view of the course of the osteotome in removing the tubercle. (Bottom drawing.) Lateral view. The deformity has been removed and the tendon falls back into place.

patients, six of whose knees were operated upon (Table I), (3) autogenous-bone pegging of the epiphyseal tongue at the tubercle to the tibial diaphysis (loose fragments may be removed)—three cases (Table I).

Up to this time, although our surgical approach to this problem had been successful with respect to relieving the symptoms and bringing about fusion of the tubercle, we still had in most instances the objectionable knob-like deformity on the knee. It was therefore recognized that if this deformity was to be removed, it would have to be dealt with in a more radical manner; therefore, the following technique was carried out:

### *Operation*

Under general anaesthesia and with a tourniquet, a two and one-half inch transverse incision just below and across the prominence of the tubercle or a longitudinal incision of similar length may be made just medial to the tubercle (Fig. 1). The patellar tendon is incised longitudinally over the prominence of the tubercle. With a thin osteotome, one inch in breadth, introduced through the incision in the tendon, a longitudinal wedge-like opening is made in the tubercle. The thin cortical and periosteal portion of the tubercle, to which the tendon is attached, is reflected on each side. With a sharp curette, fragments and débris are removed from within the tubercle. When, through too much excision, there seems to be too large a defect, one may reach down into the medullary portion of the upper portion of the tibia with a curette and produce enough cancellous bone to fill the defect. The tendon, with cortex and periosteum attached, is then allowed to fall back into place. The area is impacted in order to minimize the former bulging. After closure, a pressure dressing is applied and a cylinder cast is worn for two weeks. The rehabilitation period is usually short. In this group, there were seven patients of whom three were involved

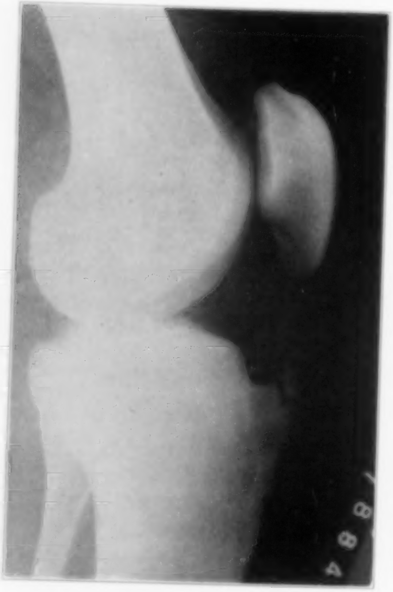


FIG. 5

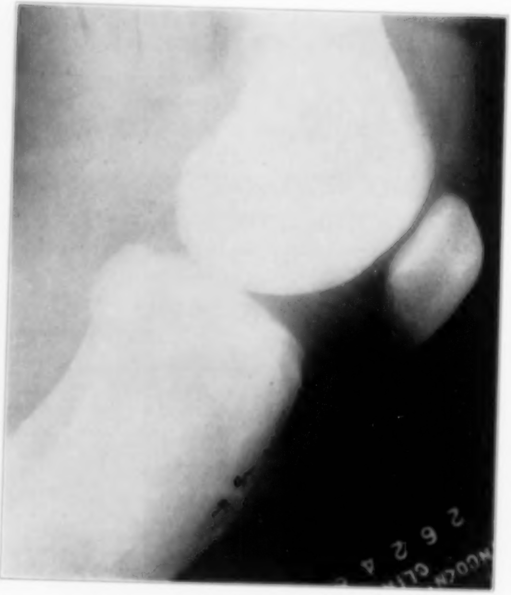


FIG. 6

Fig. 5: Case 1. Roentgenogram made in October 1951 showing the enlargement of the tubercle following
drilling of the region six years before. Adequate cast treatment was followed by recurrent periods of disabil-
ity. The operation had relieved the symptoms and ended the disability, but did not remove the knob-like
prominence. Just before this roentgenogram was made the patient had fallen violently striking the knee.
Note the loose bony fragment.

Fig. 6: Case 2. Roentgenogram of November 1954 showing enlargement of the tibial tubercle; the tract
of autogenous-bone pegs driven into the tubercle in 1942 when the patient was fifteen years of age is still
visible (arrows). The operation had relieved the symptoms and ended the disability, but had not removed
the knob-like prominence.

bilaterally. In ten of the patients upon whom this procedure was carried out (Table I), there were no complaints; there was no disability, impairment of function, or discomfort. There were several in whom there developed some prominence of the tubercle region but all were symptomless.

Because of the fact that at times some excessive prominence still developed, the results were not considered satisfactory. A review of the anatomy disclosed that the lower patellar tendon spreads itself out widely over the anterior upper end of the tibia and that the terminal fibers are attached well below that portion of the epiphysis which is called the tibial tubercle. The tubercle hangs down, tongue-like, from the upper tibial epiphysis, and it may be met by a lower epiphyseal body arising from the anterior upper portion of the shaft, these two centers of ossification growing toward each other. This frail body, because of its prominent location, is sure to be the target of frequent injury. Once separated, it often fails to unite securely. If it has any influence on the growth of the adolescent leg, we have not been able to discover it among the forty-one knees which were operated upon. Once separated from its bed, the tubercle has little opportunity to be of functional value and it certainly becomes a physical and may even be an emotional liability.

It was suggested by Dr. C. F. Ferciot [1], that the patellar tendon be split longitudinally over the tibial tubercle, be elevated subperiosteally (Fig. 2), and be retracted to each side, thus exposing the entire tubercle. The cortex and the cancellous bone, as well as the cartilaginous fragments or, in fact, the entire deforming area, could then be excised (Figs. 3 and 4), and the deformity completely corrected. The terminal and lateral attachments of the tendon are left intact and the upper tibial epiphysis is not disturbed. The tendon

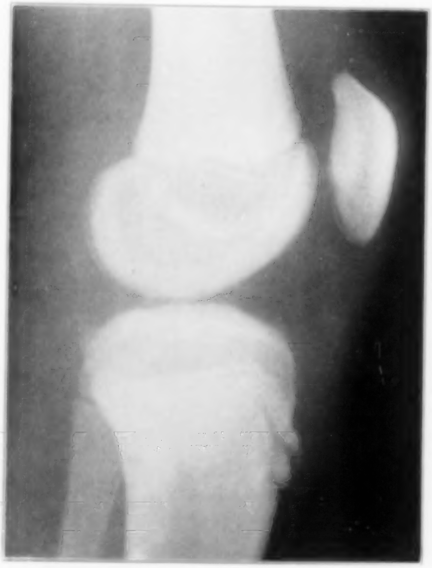


FIG. 7-A

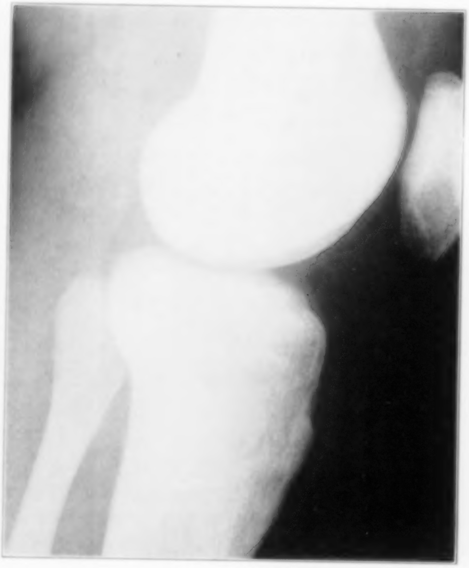


FIG. 7-B

Fig. 7-A: The patient whose tubercle is depicted had sustained repeated injury. Treatment had been conservative. The roentgenogram was made just prior to subcortical removal of fragments and impaction of the area.

Fig. 7-B: Roentgenogram made in November 1954, nearly nine years after operation. A satisfactory result cosmetically and functionally was obtained; however, there were several patients similarly operated upon in whom some enlargement of the tubercle developed.

drops back over the depressed and denuded area, the closure of the wound is accomplished, and a compression dressing and a cylinder (walking cast) is worn for two weeks.

### *Series of Patients*

This procedure has been carried out on fourteen patients of whom four were involved bilaterally, making a total of eighteen such operations. In this group our most satisfactory results, from a cosmetic, functional, and psychological standpoint (Figs. 7-A and 7-B), were achieved. Of the patients reported, all were operated upon over two years ago.

### *Indications*

Operative intervention has been decided upon only under the following conditions: (1) The patient should have had repeated attacks of severe pain, with tenderness, functional disability and deformity. (2) Even after conservative treatment (cast), the symptoms should have returned. (3) The child should have reached sufficient development in adolescence (high-school age) and height to justify such a surgical procedure. Psychological and emotional upset due to the deformity and the disability should be given consideration.

No child with this condition wants to wait the time necessary for the epiphysis to unite with the shaft of the tibia (until he is eighteen years of age); moreover, some of the injured epiphyses do not unite and will become sources of trouble in adulthood. Two of our group (Dr. F. S. Webster and Dr. Paul Goetowski), working in the Department of Student Health at the University of Nebraska, state that many young people in their twenties complain of the symptoms of this condition, having prominent tubercles that bruise and injure easily.

TABLE II

AGE AND SEX DISTRIBUTION

| Age (Years) | No. of Cases | Right | Knees Left | Bilateral | Male | Female |
|---|---|---|---|---|---|---|
| 14–20<br>average<br>16 | 18 | 3 | 9<br>24 knees | 6 | 17 | 1 |
| 10–14<br>average<br>12½ | 13 | 5 | 4<br>17 knees | 4 | 9 | 4 |

*Age*

Eighteen of the thirty-one patients were fourteen to fifteen years of age (Table II) and thirteen of the patients were from ten to thirteen years of age. There was one girl, ten years of age, upon whom I operated twelve years ago. She had a very tender tubercle which developed as the result of a bad fall. After eight weeks in a walking cast and eight weeks further convalescence and restricted activity, the pain, tenderness, and disability remained so pronounced that I operated upon her, removed the fragments, and put in bone pegs. She became free of symptoms in a few weeks, but she has a prominence in the region; there is no disability. Two of this group were eleven years of age. All three of these were girls, operated upon ten and twelve years ago. In one of them there was bilateral involvement. The ten others were between twelve and fourteen years of age. However,

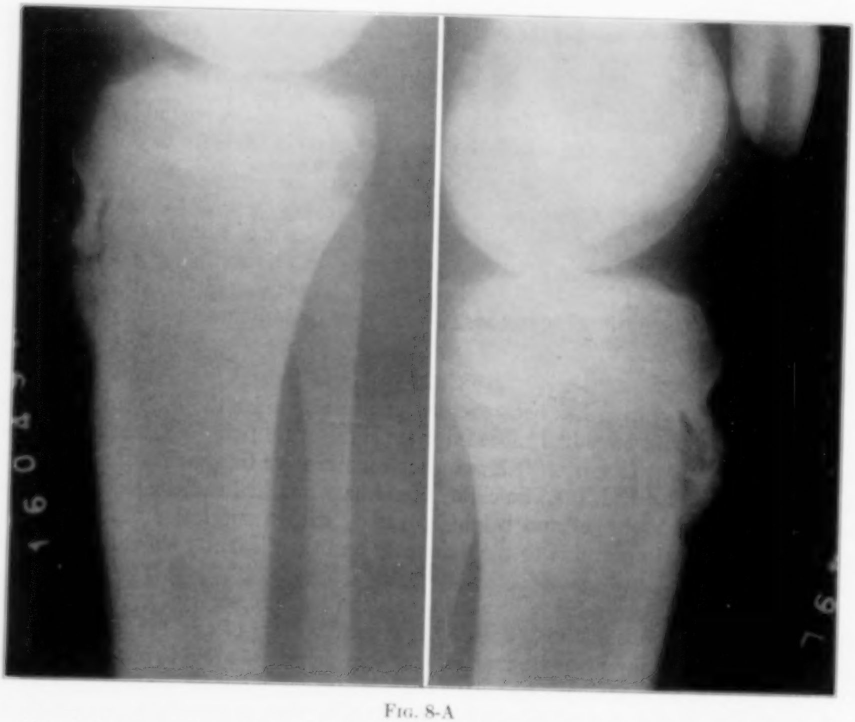


FIG. 8-A

Case 4. Roentgenogram of November 1950, showing changes in both tubercles characteristic of osteochondritis. There had been recurrent local pain and tenderness and recurrent periods of disability. The symptoms were aggravated by football. The deformed tubercles were removed completely.

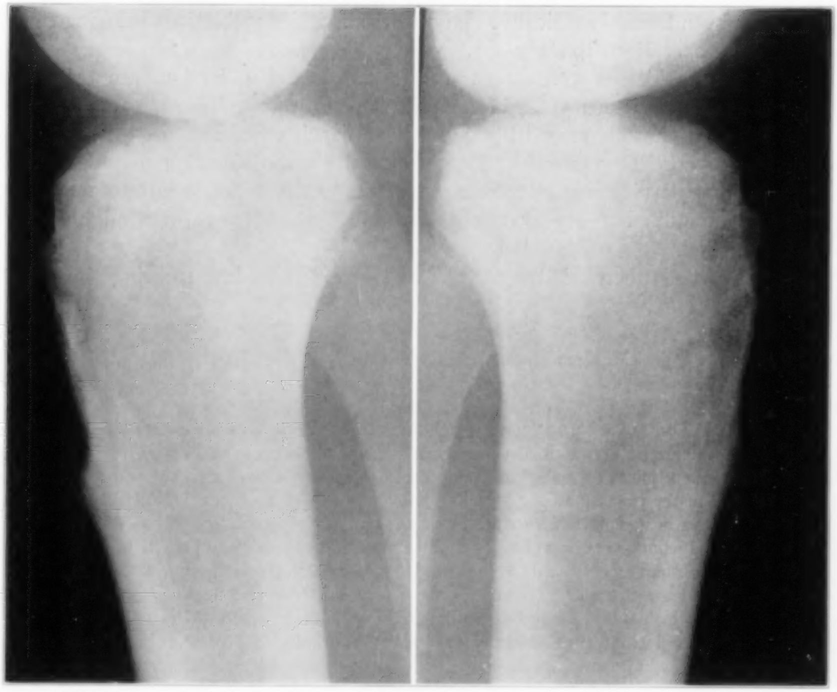


Fig. 8-B

Roentgenogram of November 1954 showing the cosmetic result. Symptoms had been promptly and completely relieved and there had been no disability and no recurrences.

the results in these youngsters were as favorable as those in the older group (Table II) as can be recognized from Table I shown with this study.

The inquiry has been made as to the development of genu recurvatum as a complication following this operation, which might result from premature closure of the anterior portion of the tibial epiphysis. In this series of forty-one operations, of which eighteen were performed according to the technique last described, there has not been a single instance of any such deformity or evidence of premature closure of the anterior portion of the tibial epiphysis. Perhaps the reason for this is that, in all of these knees, there had been such a complete separation or detachment of the tibial tubercle from the body of the tibial epiphysis, that the removal of the tubercle has had no influence on the growth of the extremity or the closure of the epiphysis.

## CONCLUSIONS

An adolescent child, having a painful enlargement of the tibial tubercle and disability, neither of which respond to conservative measures, in whom periods of disability are accompanied by recurrent episodes of pain, deserves surgical treatment which will remove the deformity, cure the discomfort and disability, with the least risk and the shortest period of convalescence.

Drilling, pegging, and removal of fragments followed by impaction, can be used successfully to fuse the tubercle and to relieve the symptoms, but an unpleasant deformity often remains, unless the tubercle is completely removed. Removal gives a good result cosmetically.

Over a twenty-year period, thirty-one patients with so called "Osgood-Schlatter's disease" have been treated surgically. Ten of these had bilateral lesions bringing the total number of knee operations to forty-one.

Of this group, thirteen were over ten years of age and under fourteen years of age. Eighteen were over fourteen years of age. The results were uniformly satisfactory with the exception that those having drilling and bone-pegging had increased deformity, and those having subcortical removal of loose fragments and deforming material with impaction and those having complete removal of the entire tubercle have a much better cosmetic and functional result because a deforming prominence which might be easily injured is removed.

Removal of the tubercle is the surest and shortest procedure to bring about a complete and lasting cure.

1. Ferciot, C. F.: Surgical Management of Anterior Tibial Epiphysis. Clin. Orthop., **5:** 204–206, 1955.

## DISCUSSION

Dr. Anthony F. DePalma, Philadelphia, Pennsylvania: It has been my experience that youngsters afflicted with osteochondrosis of the tibial tubercle rarely complain because of the presence of a prominence on the front of their knee joint. They do, however, object to the restriction of activities which is often forced upon them because of the existing lesion. My chief problem, in most instances, is not with the youngster, but with the parents whose child has a tender lump on the anterior aspect of the knee. It may be that I have not encountered as many cases as Dr. Thomson, but I do not recall any patient to whom this lesion was a detriment to normal emotional development. I have, on rare occasions, encountered patients with symptoms of sufficient severity which failed to respond to the orthodox method of treatment, and I have noted a few cases in which the prolonged disability produced in otherwise healthy, active, adolescents did justify some form of surgical intervention, in order to halt the pathological process. It becomes apparent that in a few instances surgical measures are indicated.

As Dr. Thomson experienced, I too found that drilling of the tubercle did terminate the symptoms and did result in rapid healing. The residual prominence, however, invariably was larger than the one before the operation. For this reason, I have discarded the method.

It is essential to point out that in the early stages of this disorder, no roentgenographic evidence of bone involvement may be discerned. However, there is definite clinical and roentgenographic evidence of thickening of the patellar tendon. Ferguson pointed out that the primary lesion is in the tendon, near its point of insertion into the tubercle, that the disorder is caused by stress, is developed by rapid growth and is expanded on the patellar ligament near its bony insertion. The resulting hemorrhage, swelling and degenerative changes in the tendon are primary. The irregular ossification within the underlying bone is secondary. He proposed making longitudinal cuts in the tendon for decompression and relief of the circulatory embarrassment of the underlying bones. I have performed this procedure many times. It relieves the patient of pain and induces healing of the tubercle. However, it does not minimize the protuberance; but it does not increase it. It may well be that the same factors are active in Dr. Thomson's procedure, and, hence, the excellent results. In addition, he removes the deforming osseous elements which makes this procedure even more attractive.

Dr. Thomson (closing): I am very sorry that Dr. Charles Goff, who had requested an opportunity to discuss this subject, is not here, as he wished to emphasize the fact that this condition is essentially traumatic and not a disease or aseptic necrosis of this epiphyseal body. Osgood in his original description recognized this fact. Dr. Goff in his book, *Legg-Calvé-Perthes Syndrome*, emphasizes the difference in these conditions and the importance of recognizing these differences in relation to their treatment. Therefore, in our approach to the problem of treatment, we must emphasize conservatism, but where this fails, the surgery that is administered should aim at completely removing not only the symptoms but also the deformity.

I am inclined to feel that we are too prone to ignore minor deformities that may worry some sensitive youngsters and to try to convince them that these deformities are of no moment. They are particularly important to girls and often have an influence on their development.

# THE ETIOLOGY OF PRE-ADOLESCENT KYPHOSIS

BY ALBERT BARNETT FERGUSON, JR., M.D., PITTSBURGH, PENNSYLVANIA

*From the Orthopaedic Service, Children's Hospital, and the Orthopaedic Department, University of Pittsburgh, Pittsburgh*

Dorsal-wedging round-back in adolescents is also known as kyphosis juvenilis, Scheuermann's disease, and vertebral epiphysitis. Mild degrees of this condition are symptomless; but when it progresses to a serious degree, it can produce definite adolescent and adult disability—both functional and cosmetic.

A review of cases of this disease reveals information that is of help in preventing the deformity. This information specifically relates to the fact that persistent anterior vascular grooves in the thoracic vertebral bodies appear to be a forerunner and a contributing cause of dorsal-wedging round-back.

## PAST HISTORY

The normal dorsal kyphos has been related to mechanical stress caused by the upright posture. It has been assumed that increases in this curvature follow an increased load, such as that due to excessive body weight.

Lambrinudi implicates tight hamstring tendons by noting that excessive flexion is required on forward bending to compensate for the failure of the pelvis to flex on the hips.

Whatever the cause of the increased stress, the mechanism of production of the kyphos has been thought by Schmorl to be due to a disturbance of the disc. It has been felt that the so-called Schmorl's node, ascribed to herniation of the disc, results in increased pressure on the vertebral body anteriorly as the cushioning effect of the disc is lost with herniation. Such pressure is presumed to result in growth disturbances of the epiphyses of the vertebra anteriorly; a wedging of the body takes place with growth.

The irregular ossification of the epiphyses themselves have been implicated as a primary cause of deformity in the absence of Schmorl's nodes. Such disturbances have been ascribed either to circulatory interference or to infection of the epiphyses.

Cases of early wedging round-back may be seen before the appearance of the epiphyses as an ossifying growth center. This makes it difficult to ascribe irregular epiphyseal ossification as a primary cause of the deformity, although it may well be a secondary effect.

The view that anterior vascular grooves of the vertebrae may play a part in the development of dorsal-wedging round-back was originally elaborated by Ferguson in 1949.

## NORMAL SPINE DEVELOPMENT

Two observations may be made following a review of unselected lateral chest films. These are: (1) that the normal kyphos is principally in the proximal portion of the spine at the fifth, sixth, and seventh thoracic vertebrae and (2) that the time for normal closure of those bodies developing with a persistent anterior vascular groove is in the age group seven to ten years old.

A total of 153 unselected roentgenograms of the chest were reviewed in the age group from six to eleven years. Most of these had been made on routine chest examination on admission to the hospital. None of these films had been made because of pathological conditions of the spine.

In the age group from six to seven years 38 per cent of twenty-six patients had some remnant of an anterior vascular groove. In the group seven to eight years old it was

TABLE I

Normal Spine Development

| Age (*Years*) | No. of Cases | Grooves Persistent (*Per cent*) |
|---|---|---|
| 6 to 7 | 26 | 38 |
| 7 to 8 | 39 | 30 |
| 8 to 9 | 32 | 25 |
| 9 to 10 | 35 | 17 |
| 10 to 11 | 21 | 19 |

present in 30 per cent of thirty-nine roentgenograms. Minimal wedging occurred in the thoracic spine in the region of the fifth, sixth, and seventh thoracic vertebrae.

An indentation of the superior and inferior angles of the anterior border indicating beginning ossification of the vertebral epiphyses took place in 4.6 per cent of the spines in the age group seven to eight years old.

The percentage of persistent anterior vascular grooves dropped still further in the age group eight to nine years old. In thirty-two patients, the groove was present in 25 per

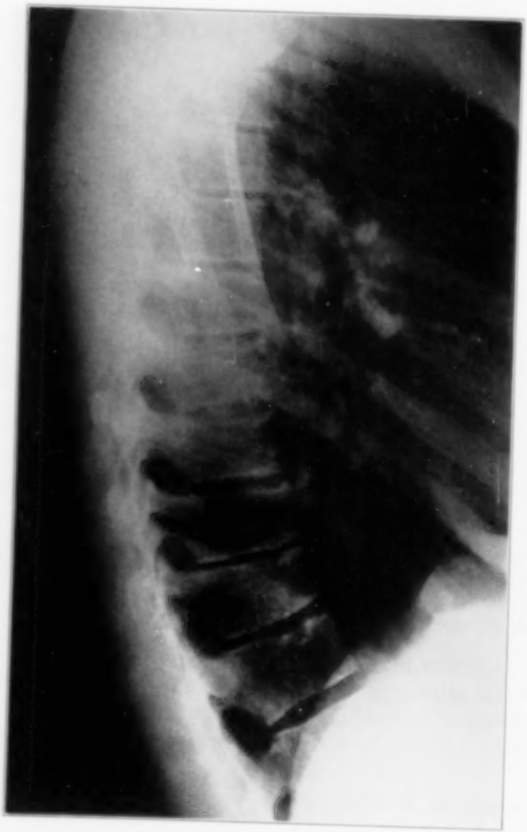


Fig. 1-A

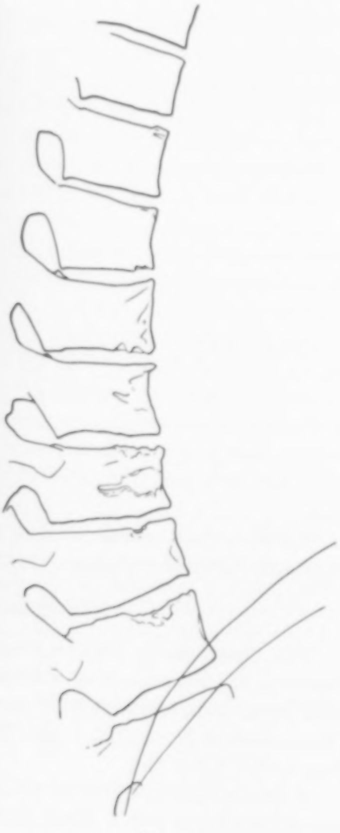


Fig. 1-B

Figs. 1-A and 1-B: A fourteen-year-old female had involvement of the thoracic vertebrae by Schmorl's nodes. There was some evidence that persistent anterior vascular grooves had entered into the wedging, since a remnant of the groove could be seen in the middle of the vertebra. Anteriorly, the groove was closed by the wedging.

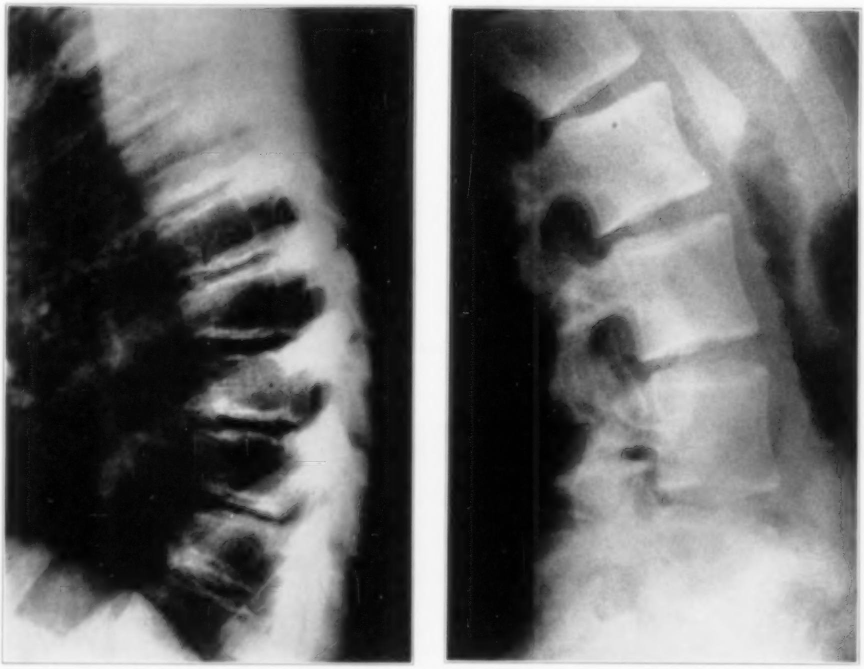


FIG. 2-A FIG. 2-B

A fifteen-year-old male had a marked round-back clinically.

Fig. 2-A: Lateral roentgenogram of the thoracic spine. The central wedged vertebra had a persistent anterior vascular groove. Epiphyseal irregularity was present not only at this vertebra but at others above and below the site of the wedging. In the others it was less marked.

Fig 2-B: A lateral roentgenogram of the lumbar spine. The lordosis accompanying the thoracic kyphos is seen.

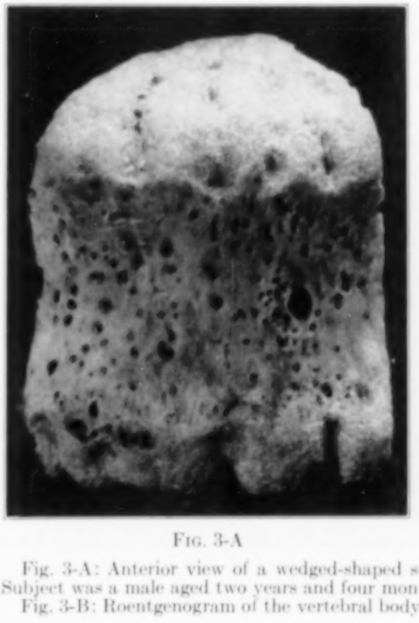


FIG. 3-A

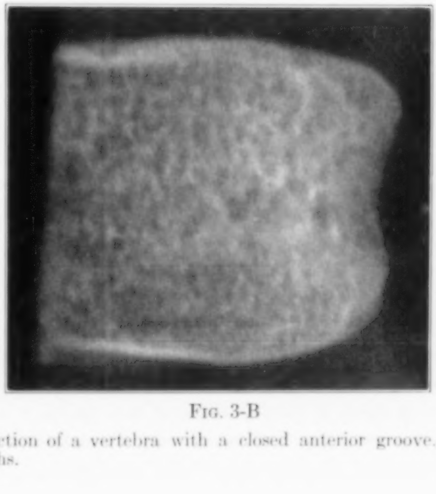


FIG. 3-B

Fig. 3-A: Anterior view of a wedged-shaped section of a vertebra with a closed anterior groove. Subject was a male aged two years and four months.

Fig. 3-B: Roentgenogram of the vertebral body.

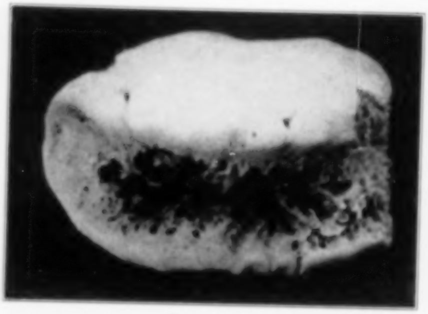


FIG. 4-A

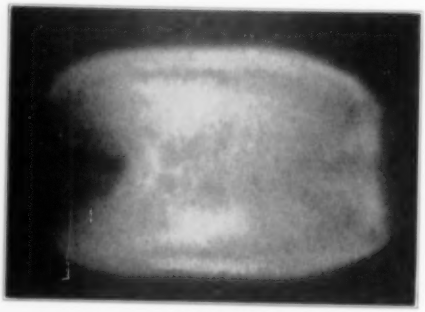


FIG. 4-B

Fig. 4-A: Anterior view of the body of the vertebra taken at postmortem examination. The extensive character of the groove is seen, although it does not extend into the body as deeply as some.

Fig. 4-B: Lateral roentgenogram of the vertebral body.

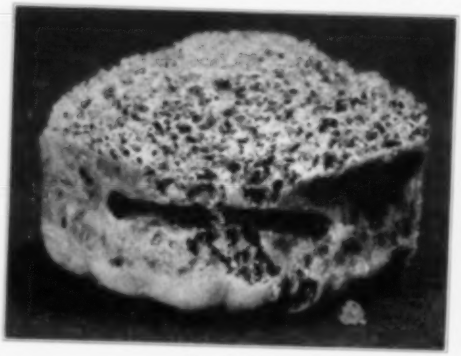


FIG. 5-A

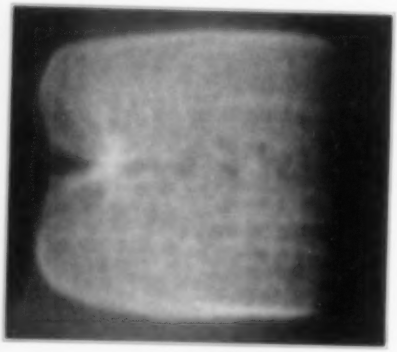


FIG. 5-B

Fig. 5-A: Anterior view of wedged-shaped sections of vertebral body with a closing vascular groove. Subject was a male three years and eight months old.

Fig. 5-B: Lateral roentgenogram of the vertebra.

cent. In 25 per cent, there was wedging in the area of the fifth, sixth, and seventh thoracic vertebrae; and 40 per cent had an early indentation of the anterior border of the vertebra.

In the age group nine to ten years old only six of thirty-five (17 per cent) had some vestige of a groove remaining. One had an early round-back deformity. Wedging in the region of the fifth, sixth, and seventh thoracic vertebrae took place in twenty-seven of the thirty-eight. An indentation of the anterior border was present in 70 per cent and epiphyses were appearing in 14 per cent.

The age group ten to eleven years yielded twenty-one cases; in four (19 per cent) some vestige of an anterior groove was seen. There were no patients in whom the groove was open to any marked degree.

## ANATOMY

The anterior vascular groove is occupied by a large endothelial-lined blood lake formed by the confluence of vessels at this point. When the soft tissues have been completely removed from the bone by immersion in sodium hydroxide, the remaining skeletal structure can be visualized. The groove extends a varying width across the anterior border of the vertebra depending on the degree to which the groove remains open. Grooves of which there is only a minimal vestige have a considerable portion of the anterior border of the vertebra well supported. Photographs of the vertebral skeleton with a persistent groove are shown with lateral roentgenograms of the body of the vertebra.

TABLE II

Persistent Vascular Grooves *

| Case No. | Sex | Age (*Years*) | Vertebrae Involved | Progression (*Degrees*) | Follow-up (*Years*) |
|---|---|---|---|---|---|
| 75727 | M | 5 | T9 to T12 | 3.0 to 5.9 | 1 |
| 40540 | M | 5½ | T7 to T9 | 4.7 to 7.3 | 9 |
| 72967 | F | 6 | T7 to T9 | 3.6 to 5.2 | 6 |
| 86966 | F | 6 | T6 to T9 | 3.7 to 5.3 | 2 |
| 89240 | M | 6 | T6 to T9 | None | 4 |
| 80887 | F | 6½ | T8 to T11 | 5.7 to 8.3 | 3 |
| 61024 | F | 6½ | T6 to T8 | 4.0 to 4.3 | 3 |
| 84936 | M | 7 | T6 to T8 | None | 2 |
| 73128 | M | 8 | T7 to T10 | 4.7 to 9.5 | 5 |
| 60669 | M | 8 | T6 to T8 | 3.0 to 5.0 | 4 |
| 61683 | F | 8½ | T6 to T8 | 3.5 to 6.7 | 4 |
| 47771 | F | 9 | T8 to T11 | 3.0 to 10. | 8 |
| 52593 | M | 9 | T9 to T12 | 4.6 to 7.0 | 6 |
| 80712 | M | 9 | T8 to T10 | 4.0 to 5.6 | 2 |
| 15082 | M | 10 | T7 to T9 | 6.8 to 9.3 | 3 |
| 76724 | F | 10 | T6 to T9 | 6.3 to 8.0 | 2 |
| 78332 | F | 11 | T6 to T8 | 4.5 to 5.3 | 1 |
| 90031 | F | 11 | T6 to T9 | 4.5 to 6.2 | 3 |
| 73959 | M | 12 | T8 to T9 | 2.5 to 4.0 | 1 |
| 04176 | M | 15 | T8 to T10 | None (grooves closed anteriorly) | 3 |
| 84799 | M | 17 | T8 to T10 | 8.6 to 10 | 2 |

* Number of cases: 21; progression of round-back deformity: 18

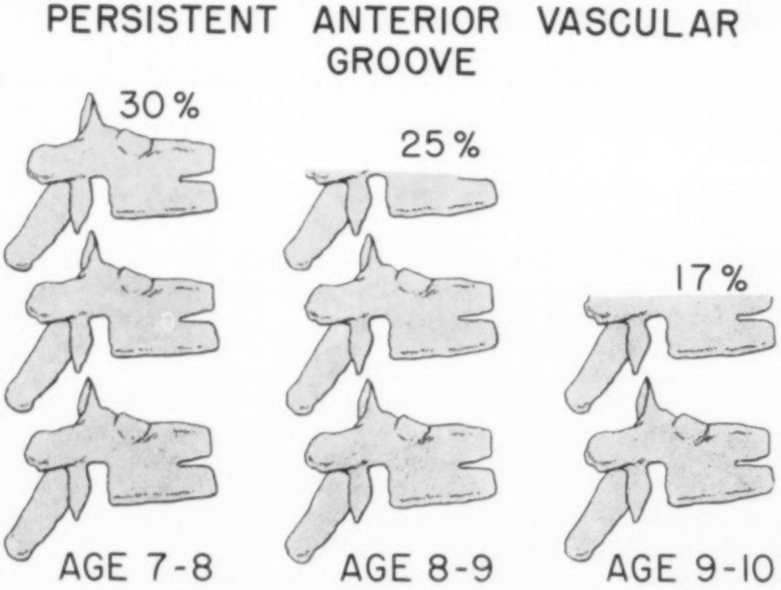


Fig. 6

Diagram illustrates the diminishing incidence of anterior vascular grooves in the age group seven to ten years. The figures are based on a review of normal lateral spine roentgenograms.

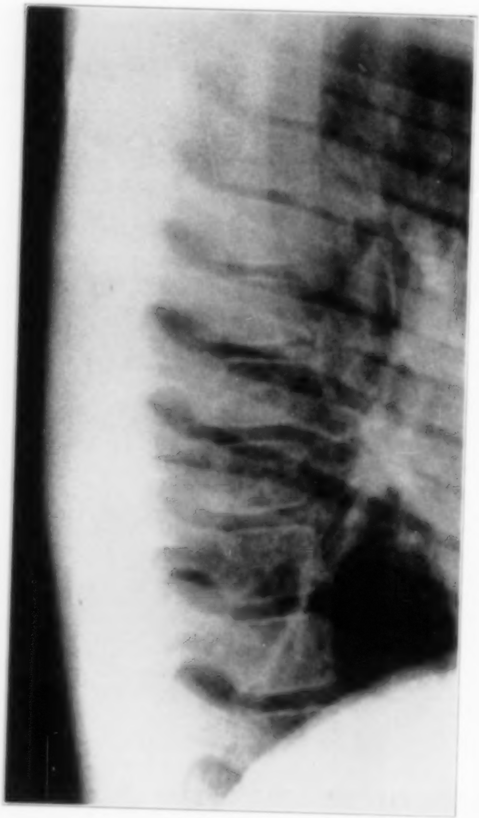


FIG. 7-A

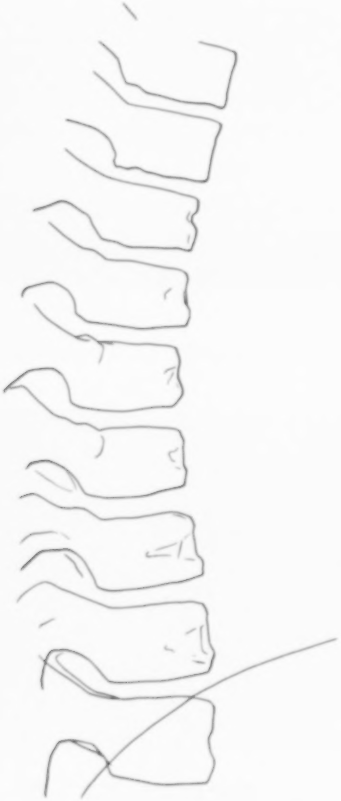


FIG. 7-B

Fig. 7-A: The normal dorsal kyphos occurs principally at the fifth, sixth, and seventh thoracic vertebrae. Subject was eight years old.

Fig. 7-B: Line drawing made from roentgenogram. The anterior grooves are closed.

## DISCUSSION

It appears that the anterior vascular grooves begin closing first in the lower thoracic vertebrae. In the area of the fifth, sixth, and seventh thoracic vertebrae wedging develops so frequently as to be regarded as normal and as primarily responsible for the posterior thoracic curve. This wedging, as it develops, closes the anterior vascular grooves. Thus, a persistence of the anterior vascular grooves that could be potential to the development of a round-back deformity would tend to be in the mid-thoracic area.

When the grooves are persistent in the mid-thoracic and low-thoracic area, other vertebrae may be involved distal to the curve at the fifth to the seventh thoracic vertebrae; this may be sufficient to produce an accentuated thoracic curve or round-back deformity. It is the addition of wedging in the lower thoracic vertebrae to the normal kyphos at the fifth, sixth, and seventh thoracic vertebrae that produces a curve severe enough to be regarded as a disability.

The evidence that persistence of the anterior vascular grooves is a factor in dorsal-wedging round-back has to be pieced together. Wedging sometimes obliterates the grooves. In the fourteen-year-old patient and in older patients, occasionally, there is definite evidence that it has been persistent. This may consist of the groove itself or of a dense line

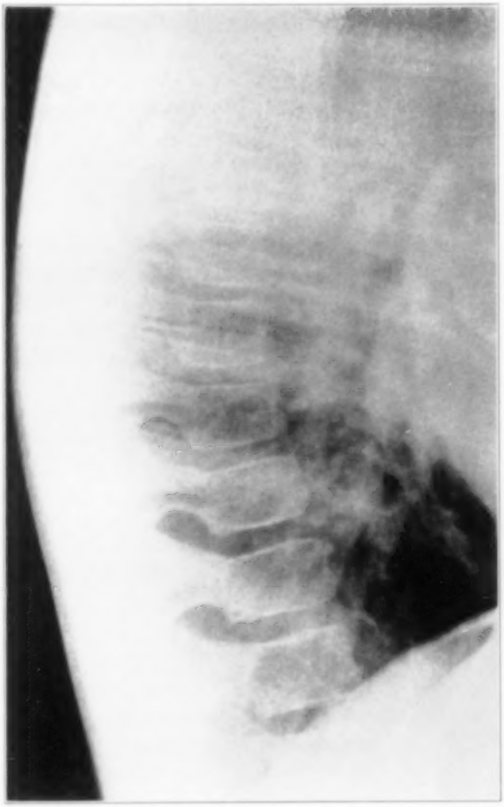


FIG. 8-A

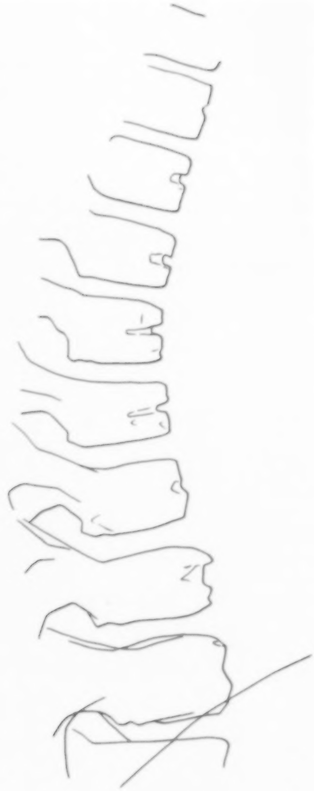


FIG. 8-B

Fig. 8-A: A mild increase in dorsal curvature was brought about by the extension of the wedging into the eighth thoracic vertebra where there was a persistent anterior vascular groove. Subject was nine years and ten months old.

Fig. 8-B: The line drawing made from the roentgenogram emphasized the details of the anterior vascular groove.

in the region of the groove consistent with overriding of the trabeculae that might occur as a result of collapse.

In the age group below fourteen the occurrence of early wedging in vertebrae with persistent grooves is more noticeable.

Twenty-nine patients with round-back were examined roentgenographically. In twenty-one of these roentgenograms had been made and eighteen showed progression in a follow-up of one to nine years. This group is summarized in Table II.

The roentgenograms of eight additional cases were seen in which a definite round-back deformity existed. Seven of these showed evidence of persistent grooves. One had a round-back deformity without any evidence of persistence of the grooves.

It is apparent in patients over fourteen that the vertebral epiphyseal plates became irregular in those areas of the thoracic spine in which marked wedging had occurred. This may be interpreted as a secondary rather than the primary cause of juvenile kyphosis.

One occasionally sees wedged vertebrae without evidence of persistence of the vascular grooves. On these films there is well formed bone constituting the anterior border of the vertebrae. Further wedging would not be expected; since the expectation would

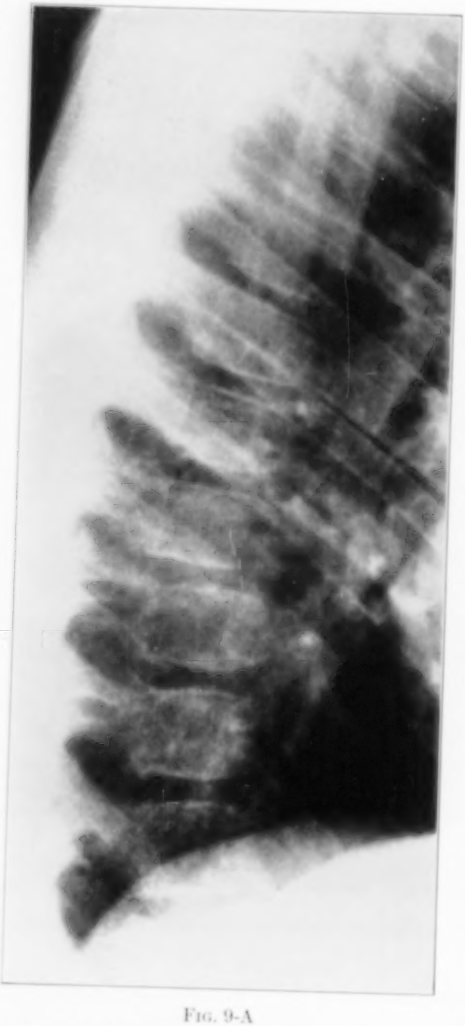


Fig. 9-A

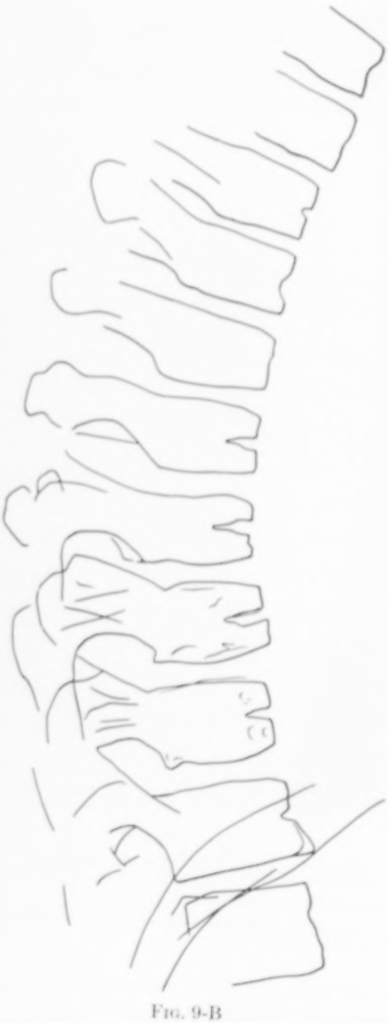


Fig. 9-B

Fig. 9-A: Further extension of the wedging process into the lower thoracic vertebrae with anterior grooves still open. Subject was eight years and ten months old.

Fig. 9-B: Line drawing from the roentgenogram.

be that the skeletal structure and the body mechanics had reached an equilibrium. One patient showed a build-up of bone in an unwedged vertebra at the border of the vascular groove in the manner of a supporting strut.

The point of this paper is the transfer of the treatment of dorsal-wedging round-back from the sixteen-year-old patient and the older patient to the group from eight to sixteen —even earlier if it is definitely indicated. Persistence of the anterior vascular groove appears to be the forerunner of this disease; and in the presence of poor posture clinically with early development of round-back and compensating lumbar lordosis, treatment is indicated in the interest of preventing further deformity.

Persistent anterior vascular grooves do not in themselves constitute the only cause of a dorsal-wedging round-back. They do, however, create a point of weakness in the vertebral structure. Such weakness is clearly evident when the vertebra is debrided of its soft tissue and cartilage. The anterior vascular groove then stands out as an unsupported area which needs only abnormal stress to cause its collapse. Such stress on top of that due to the upright posture may be caused by postural mechanics. Forward-bending exercises of the spine in the presence of a pelvis anchored by the hamstrings may result in the necessity of excessive flexion in the thoracic area. Habitual sitting attitudes in which the thoracic spine is excessively stressed may be equally at fault.

## TREATMENT

The most simple measures consist in discarding the pillow, the use of a bed board, periods of recumbency on a flat unyielding surface, and postural exercises designed to obliterate the lumbar lordosis. In addition, tight hamstrings should be stretched and poor postural habits should be eliminated.

To these may be added a spinal flexion brace. This brace stops at the twelfth thoracic vertebra and is designed to obliterate the lumbar lordosis. The flat lumbar spine may be achieved by bending forward. If fixed in this position by a brace, the patient must hyperextend the thoracic spine in order to secure an upright posture, and the anterior portion of the thoracic spine is relieved of stress. A period of follow-up of the treated patients to show the ability or lack of ability of these conservative measures to prevent wedging is not available at this time and must be done in the future.

More severe measures in the presence of a well-established deformity which is disabling include wedging casts and spinal fusion.

## SUMMARY

From a review of normal spines and spines afflicted with wedging round-back deformity in the thoracic region, it appears that persistence of the anterior vascular groove in the bodies of the thoracic vertebrae may play a role in the production of deformity by inviting anterior collapse of the vertebrae. Actual round-back deformity is the result of wedging of the vertebrae below the region of the fifth, sixth, and seventh thoracic vertebrae. This wedging accentuates the kyphos which normally is present at the fifth, sixth, and seventh thoracic vertebrae. It is believed that there is sufficient evidence to warrant treatment of children in the eight to fourteen year old age group who show this sign by x-ray and who present early clinical evidence of poor posture with round-back and increased lumbar lordosis.

## REFERENCES

1. Ferguson, A. B.: Roentgen Diagnosis of the Extremities and Spine. Ed. 2, p. 407. New York, Paul B. Hoeber, 1949.
2. Lambrinudi, Constantine: Adolescent and Senile Kyphosis. British Med. J., **2:** 800–804, 1934.
3. Scheuermann, H.: Kyphosis dorsalis juvenilis. Zeitschr. f. Orthop. Chir., **41:** 305–317, 1921.
4. Schmorl, G.: Die Pathogenese der juvenilen Kyphose. Fortschr. Geb. Röntgenstr., **41:** 359–383, 1930.

# AVULSION OF THE INSERTION OF THE BICEPS BRACHII

## Report of a Case

BY W. R. FISCHER, M.D., AND L. A. SHEPANEK, M.D., CHICAGO, ILLINOIS

*From the Illinois Masonic Hospital, Chicago*

Avulsion of the insertion of the biceps brachii is unusual enough to warrant adding another case history to the list of those reported. There have been twenty-nine previously reported cases [3,4] and fifty-one previously unreported cases which were analyzed in a special survey [1].

### REPORT OF A CASE

R. F., a white male, aged fifty-three, was first seen in the Emergency Room of the Hospital on May 13, 1952. The patient was comatose and was found to have sustained multiple lacerations of the forehead and a comminuted fracture of the distal portion of the left tibia. Attention was not directed to the right arm for the first few days because of the severity of the other injuries.

Examination revealed a full range of motion in the right elbow, wrist, and fingers. There was tenderness to palpation at the distal end of the right arm along the course of the distal tendon of the biceps brachii and also at its insertion into the radial tuberosity. Although the patient was right-handed, strength of flexion and supination was only fair and had definitely decreased. When the right elbow was flexed and the forearm supinated, the mass of the biceps muscle retracted proximally. A diagnosis of a rupture of the tendinous insertion of the biceps brachii was made.

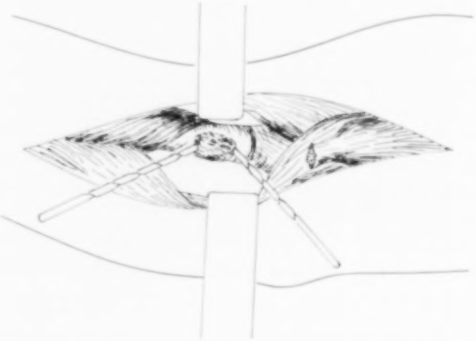


FIG. 1

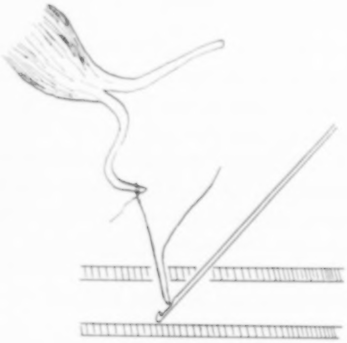


FIG. 2

Fig. 1: Diagram showing how drill holes are placed in the radial tuberosity for securing the divided biceps tendon.

Fig. 2: Drawing of a longitudinal section of the radius to show the method used to pull the tendon through oblique holes in the cortical bone (striped) of the radius with a crochet hook.

Because the patient was a laborer and needed strength in the right arm, it was decided to repair the torn tendon. On May 23, 1952, ten days after injury, repair was performed. At this time, without tourniquet, the right arm and elbow were explored through a lateral skin incision which curved medially across the antecubital fossa. The biceps brachii was found to be retracted toward the origins of the long and short heads of the muscle, and the distal tendinous end was coiled with the main muscle mass. The distal end of the tendon was enlarged and was grayish yellow in color, giving an appearance of degeneration. The small frayed tag remaining on the radial tuberosity was identified and removed. Two holes were drilled through the radial tuberosity (as described by Goldberg), the tendinous insertion was split in half, and one end of the divided tendon was passed through the drill holes and sutured to the other end of the divided tendon. Dressings and a plaster cast were applied with the elbow held in a flexed position and the forearm in supination.

Convalescence was uneventful and the cast was removed in three weeks. After its removal a sling was used for two weeks, although the patient was encouraged to exercise his elbow gently. He was last seen on

September 10, 1955, and at this time there was a complete range of motion in the elbow and full power in the right arm had been entirely regained.

## COMMENT

The diagnosis of avulsion of the biceps brachii was made only after the patient had regained consciousness and was able to call attention to the injury. Apparently the mechanism of injury had been a direct blow on the insertion of the biceps muscle when the arm was thrown out with the elbow in full extension. The pathological appearance of the tendon at the time of operation indicated that the tendon may not have been entirely normal prior to injury. Except for weakness of flexion of the elbow and supination of the forearm, function was surprisingly good prior to repair.

The method of repair described was chosen because it was felt that in this case function would be restored most adequately. Other methods of repair [1], such as attaching the insertion to the ulna or attaching the insertion to the brachialis muscle [4], apparently have yielded good results.

## REFERENCES

1. Dobbie, R. P.: Avulsion of the Lower Biceps Brachii Tendon. Analysis of Fifty-one Previously Unreported Cases. Am. J. Surg., **51**: 662–683, 1941.
2. Goldberg, David: Bone-Suture Guide. A New Instrument for Suturing Soft Tissue to Bone. J. Bone and Joint Surg., **34-A**: 996–997, Oct. 1952.
3. Goldenberg, Raphael: Avulsion of the Distal Biceps Brachii Tendon. J. Med. Soc. New Jersey, **47**: 114–115, 1950.
4. Schlossbach, Theodore: Rupture of the Biceps Brachii. Case Report. J. Med. Soc. New Jersey, **47**: 166–167, 1950.

# BONE METABOLISM

## II. TOXICITY AND METABOLISM OF RADIOACTIVE STRONTIUM ($SR^{90}$) IN RATS*

BY ROBERT D. RAY, M.D., PH.D., DUNCAN M. THOMSON, PH.D., NORVELLE K. WOLFF, M.S., AND DUANE LAVIOLETTE, B.S., SEATTLE, WASHINGTON

*From the Division of Orthopaedic Surgery, University of Washington School of Medicine, Seattle*

### INTRODUCTION

The purpose of the following experiments was to determine the dose of $Sr^{90}$ which, injected intraperitoneally in rats, would be followed by death of approximately half of the animals during a post-injection period of fifty to sixty days ($LD_{50}$/50–60 days) and to study the metabolism of $Sr^{90}$, as well as the histological and possible physiological changes induced by beta radiation at this dose level. The many potential industrial, as well as experimental, uses of this isotope would appear to justify these experiments, both from a clinical and a theoretical point of view.

It has been reported in the literature that the acute lethal dose ($LD_{50}$/30 days) for $Sr^{89}$ in young mice is eight microcuries per gram of body weight [5], and that 2.9 microcuries of $Sr^{89}$ per gram body weight is 85 per cent lethal in two weeks in fifty-gram rats [13]. However, there is no data in the literature concerning the toxicity of $Sr^{90}$. Metabolic studies of $Sr^{89}$, $Sr^{90}$, and $Ca^{45}$ have been reported [6,7,9,14,15,17,19,21,22,23], but in these studies the isotopes have been used at trace levels of radiation, and the possible influence of ionizing radiation at levels sufficient to cause cellular damage in the skeleton has not been reported. On the other hand, the histological changes induced in the skeleton as a result of exposure to radiation have been studied extensively. The reported changes consist in cessation of growth, eburnation and devitalization of the bone; disappearance of the osteoblasts, disorganization of the cartilage cells of the epiphyseal plate; "severance" of the trabecular bone from the epiphyseal cartilage, oedema and fibrosis of the periosteum, and the occasional development of bone sarcomata [1,5,8,13,20]. These changes apparently are independent of the source (external or internal) or of the type of radiation (alpha, beta, or gamma) [8]; but there are quantitative differences in the response, depending on the source and energy of radiation, and on the animal species (for example, the toxic dose per kilogram body weight may be 2.5 to 150 times greater for heavy metals and radium in the rat than in man [11]). In the present study, the early metabolism of $Sr^{90}$ at the $LD_{50}$/50–60 days has been investigated, and a comparison has been made between the results obtained and those reported by other workers at trace levels of radioactivity. In subsequent papers, metabolic studies over longer periods of time will be reported, as well as experimental attempts to accelerate mobilization of $Sr^{90}$ from the skeleton.

### TOXICITY STUDIES

#### *Methods and Materials*

Eleven male Long-Evans rats, age thirty-one to forty-four days, were given a single intraperitoneal injection of carrier-free $Sr^{90}$ ** (0.5 millicurie per milliliter of solution) at doses ranging from 1.5 to 30.0 microcuries per gram body weight. Four other animals in the same age and weight range served as controls. Each rat was maintained in a stainless-steel metabolic cage and was fed a standard diet (McCollum's Diet I, slightly modified) and

---

* This paper is based on work performed under United States Atomic Energy Commission Contract AT (45-1)-344.

** By "carrier-free" radioactive isotope is meant a chemically *pure* preparation of the particular radioactive isotope or (in practice) a close approach to the pure isotope.

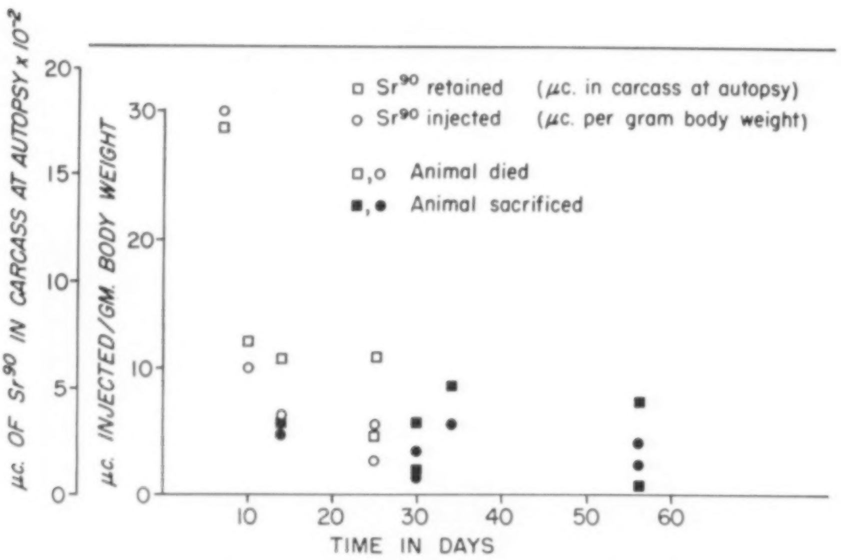


CHART I

Relationship of microcuries of $Sr^{90}$ injected and retained to survival of rats (thirty to forty days old at the time of injection).

tap water. Urinary and fecal matter were pooled and ashed in concentrated nitric acid. Determinations of the excretion of $Sr^{90}$ were made on five of the animals at three-day intervals during the experiment. At autopsy, the tibiae were removed for histological study, and the femora were removed for chemical and radioactivity determinations. The remainder of the carcass was ashed in nitric acid. Following removal from the body, the femur was weighed (wet weight), was dried to constant weight at 90 degrees centigrade (dry weight), and was ashed at 600 degrees centigrade (ash weight). The difference between the wet weight and the dry weight was calculated as the water content, the difference between the dry weight and the ash weight was calculated as the organic content of the bone.

For radioactivity determinations, the ashed femora were dissolved in nitric acid, and a suitable aliquot was evaporated to dryness on a two-inch watch glass. Total activities in urine-faeces samples and the carcass samples were determined in a similar manner. Since $Sr^{90}$ (twenty-five-year half-life) decays to $Y^{90}$ (sixty-five-hour half-life), all samples were held at least fifteen days (five half-lives of $Y^{90}$) in order to attain equilibrium. Counting was carried out with a standard beta-gamma end-window Geiger-Müller tube and a decade scaler. At least 5,000 counts were totaled for each sample in order to minimize the inherent statistical error in counting. The error in calculated total counts in femur samples was estimated to be ± 2 per cent and in excreta and carcass samples ± 16 per cent (large error in volume estimations), and the error in the count per minute-microcurie conversion factor was estimated as ± 4 per cent. Conversion from counts per minute to microcuries involves several theoretical problems (for a discussion of these the reader is referred to Siri, Chapter 13). The standard $Sr^{90}$ source used in these experiments with a known absolute disintegration rate was furnished by the Standards Laboratory, Hanford Works, Richmond, Washington.

## *Results*

### *Survival*

The relation between $Sr^{90}$ injected, estimated per cent of dose retained in the skeleton, and survival is shown in Chart I. (The method of estimation will be described under

TABLE I

TOXICITY STUDY: SUMMARY OF RESULTS

| Animal No. | Treatment (*Microcuries per Gram*) | Survival Period (*Days*) | Body Weight Onset (*Grams*) | Body Weight Final (*Grams*) | Blood Counts White Blood Cells | Blood Counts Red Blood Cells X10⁶ | Wet Weight of Femur (*Milligrams*) | Percentage of Doses in Femur | Percentage of Doses in Carcass |
|---|---|---|---|---|---|---|---|---|---|
| 2853 | 30.0 | 8 | 70 | | | | 284.0 | 4.3 | 82 |
| 2871 | 10.0 | 10 | 107 | | | | 311.9 | 2.4 | 67 |
| 2856 | 6.2 | 14 | 112 | | | | 552.2 | 4.7 | 98 |
| 3714 | 5.5 | 25 | 128 | 80 | | | 547.2 | 5.1 | 93 |
| 3711 * | 5.4 | 35 | 132 | 84 | 150 | 5.00 | 507.3 | 3.6 | 72 |
| 2866 * | 4.9 | 14 | 108 | | | | 544.6 | 3.1 | 63 |
| 3705 * | 4.1 | 56 | 118 | 107 | 3,500 | 6.97 | 508.7 | 6.4 | 91 |
| 2851 * | 3.5 | 30 | 100 | | | | 443.3 | 5.9 | 97 |
| 3713 | 2.8 | 25 | 120 | 74 | | | 473.6 | 4.4 | 88 |
| 2852 * | 1.5 | 30 | 117 | | | | 739.6 | 4.3 | 74 |
| 3712 * | Control | 36 | 125 | 210 | 6,800 † | 7.00 † | 689.4 | | |
| 3704 * | Control | 54 | 110 | 208 | | | 689.4 | | |
| 3708 * | Control | 54 | 140 | 360 | 15,000 † | 8.62 † | 1049.3 | | |
| 3710 * | Control | 56 | 140 | 301 | 5,900 † | 8.36 † | 874.7 | | |

* Animal sacrificed. † Normal values for the rat.

Metabolism Studies, Results, Femur and Skeleton.) The maximum dose of $Sr^{90}$ followed by survival of the rat for the fifty to sixty day period was 4.1 microcuries per gram of body weight, or a total dose of 491 microcuries. One other animal, injected with 2.25 microcuries per gram of body weight survived a similar period; however, two rats, injected with 2.8 and 1.5 microcuries per gram of body weight, respectively, died at twenty-five and thirty days post-injection.

### *Gross Changes*

The effects of the injection of $Sr^{90}$ on the body weights and blood counts of the rats are summarized in Table I. At the animal age selected for the experiment, the normal rat is gaining weight rapidly (two to four grams per day). Following injection with $Sr^{90}$, of the five animals in which weights were followed, four lost weight and one gained weight, the latter having been injected at a lower level of activity than the others. In ten of the eleven injected rats bloody noses developed, suggesting either an upper-respiratory-tract infection or an increased tendency toward hemorrhage. Blood counts on two of the animals revealed a depression of the white cell count, but little alteration in the red cell count.

### *Histological Changes*

At doses of $Sr^{90}$ below the level of 2 to 2.5 microcuries per gram of body weight, there were no perceptible histological changes in the epiphyseal region within thirty days after injection (Fig. 1). The epiphyseal plate was not disorganized, nor were its cells damaged. There was osteoblastic proliferation and no evidence of derangement of osteocytic transition. In the metaphyseal region, however, the trabeculae were dense, almost filling the medullary cavity, and interposed between were areas of fibrous and rather acellular marrow (Fig. 2). No myeloid elements were seen. Both osteoblastic and osteoclastic cells were lacking, and the osteocytes were reduced in number; the majority of the lacunae were empty. The trabeculae appeared immature, with persistent areas of cartilaginous matrix.

Fifty-six days after injection of 3.5 microcuries per gram of body weight of $Sr^{90}$, there was complete disruption of the epiphyseal plate (Fig. 3). The cellular elements were either absent or were severely damaged. There was complete acellularity at the junction of the epiphyseal disc and the trabecular bone ("severance" of Heller [12]). The trabeculae, as before, were dense, and no normal appearing bone elements were found (Fig. 4). The only cells which were identifiable were erythrocytes. At higher levels of activity, the rats did not survive for more than thirty-four days, and the changes in the skeleton were less pronounced. However, degenerative changes in the renal tubules were observed in histological sections of the kidneys of the rats that died early.

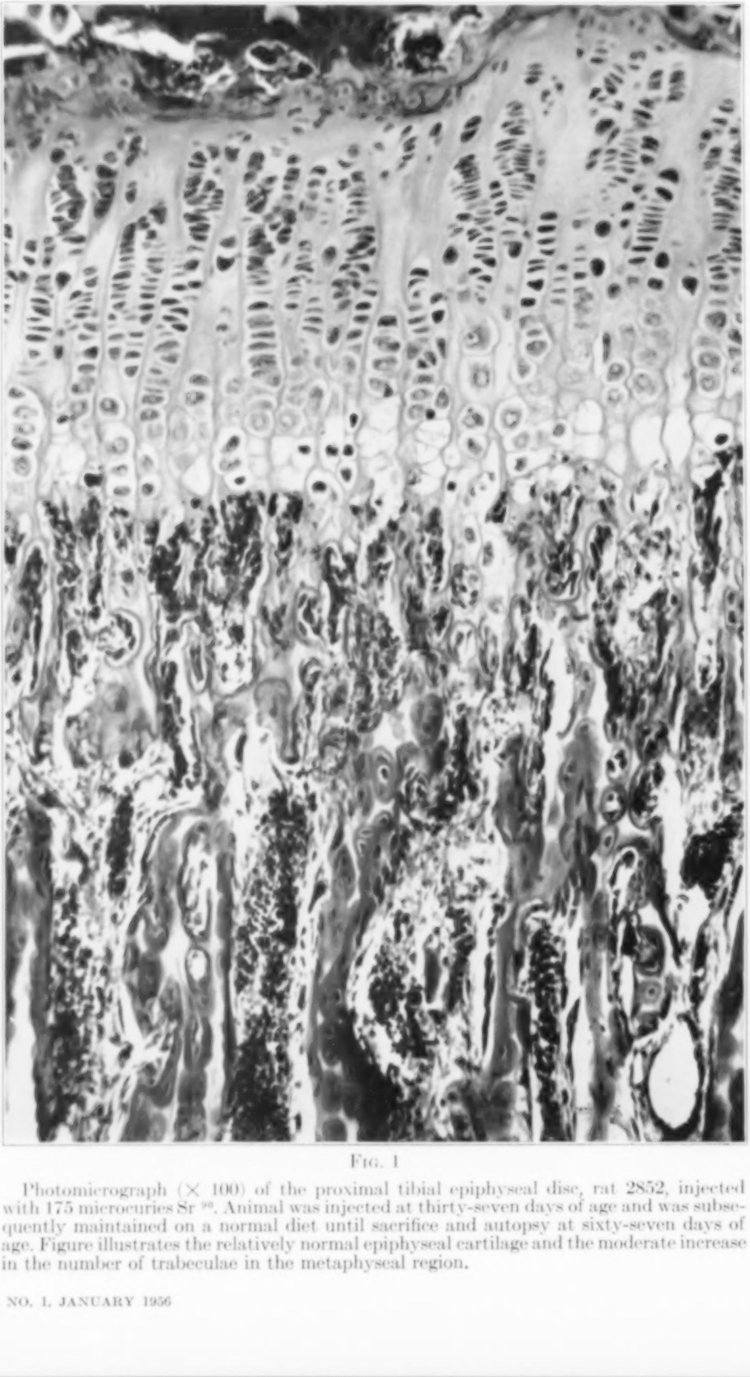


FIG. 1

Photomicrograph (× 100) of the proximal tibial epiphyseal disc, rat 2852, injected with 175 microcuries Sr $^{90}$. Animal was injected at thirty-seven days of age and was subsequently maintained on a normal diet until sacrifice and autopsy at sixty-seven days of age. Figure illustrates the relatively normal epiphyseal cartilage and the moderate increase in the number of trabeculae in the metaphyseal region.

*Discussion*

From the foregoing data, the $LD_{50}$/50–60 days for Sr $^{90}$ for the young Long-Evans rats was estimated to be 2.5 to 3.0 microcuries of Sr $^{90}$ per gram of body weight. Beta radiation of two energy levels is involved in the decay of Sr $^{90}$:

$$\mathrm{Sr}^{90} \quad \frac{0.537 \text{ Mev } \beta}{T\tfrac{1}{2} = 25 \text{ yrs}} \longrightarrow \mathrm{Y}^{90} \quad \frac{2.18 \text{ Mev } \beta}{T\tfrac{1}{2} = 65 \text{ hrs.}} \longrightarrow \mathrm{Zr}^{90} \text{ (stable)}$$

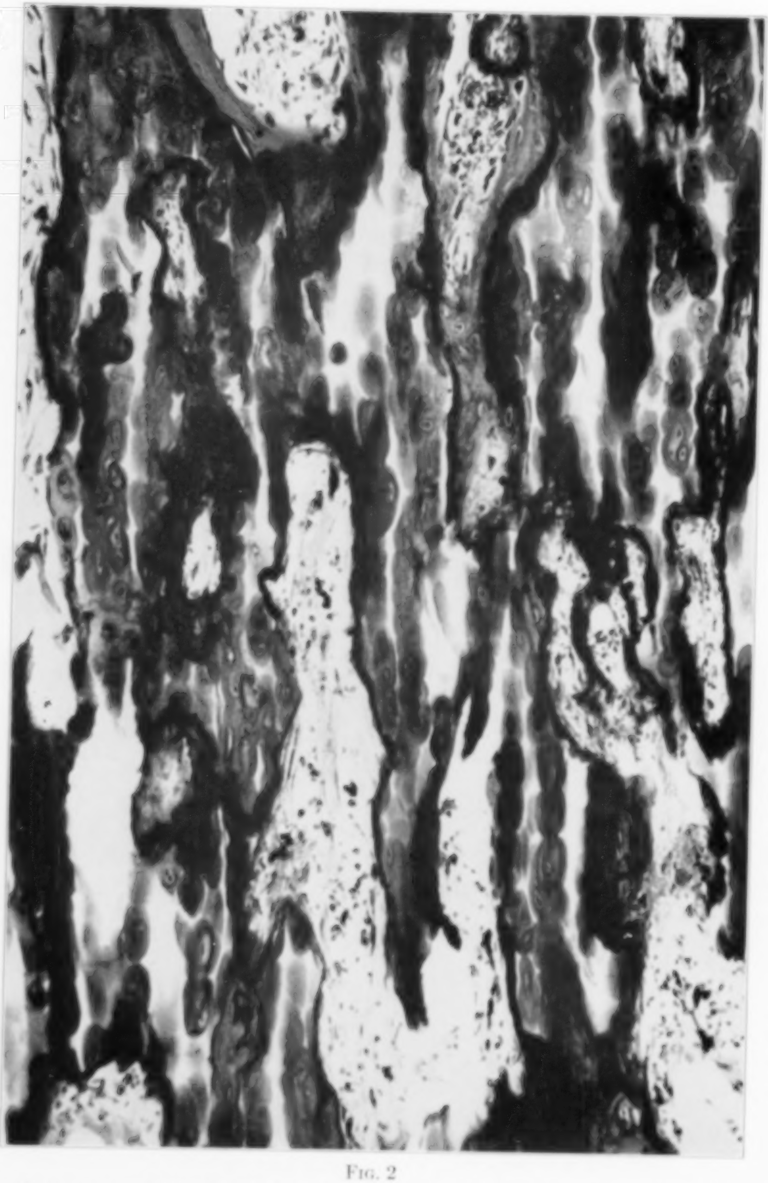


Fig. 2

Photomicrograph (× 100) of the diaphysis of the tibia of rat 2852 showing the failure of remodeling of trabeculae (osteosclerosis). This photomicrograph was made from a section just distal to that shown in Fig. 1.

(*Mev* refers to the energy of the beta particles expressed in million electron volts and $T\frac{1}{2}$ refers to the half-life of the isotope.) At the estimated $LD_{50}$ level of injection, the white blood cell count was depressed and skeletal growth was retarded. The osteosclerosis, observed histologically, suggests either that beta irradiation resulted in initial stimulation of bone formation or in early selective inhibition of bone resorption and remodeling,

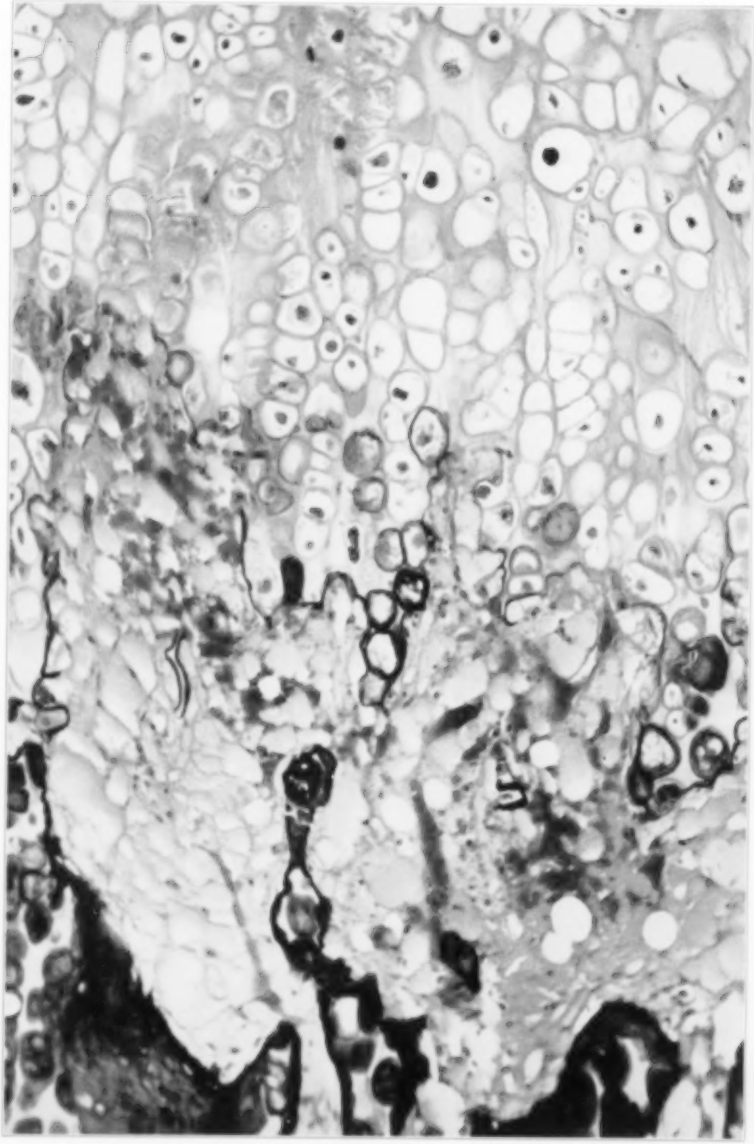


FIG. 3

Photomicrograph (× 100) of the epiphyseal plate of rat 2851 which had been injected with 350 microcuries of $Sr^{90}$ at thirty-seven days of age. Animal was maintained on a normal diet and was sacrificed and brought to autopsy at sixty-seven days of age. The photomicrograph illustrates the marked derangement of cells of the epiphyseal cartilage and the acellularity of the metaphyseal region. There are areas of hemorrhage in the metaphyseal region (not clearly shown in this photomicrograph).

changes which in turn may have been secondary to changes induced in the circulation of the bone. These changes were followed later by the development of aseptic necrosis.

## METABOLISM STUDIES

### *Methods and Materials*

Forty-one male Long-Evans rats, age forty-four to fifty-four days, were given a single intraperitoneal injection of 2.6 microcuries of carrier-free $Sr^{90}$ per gram of body

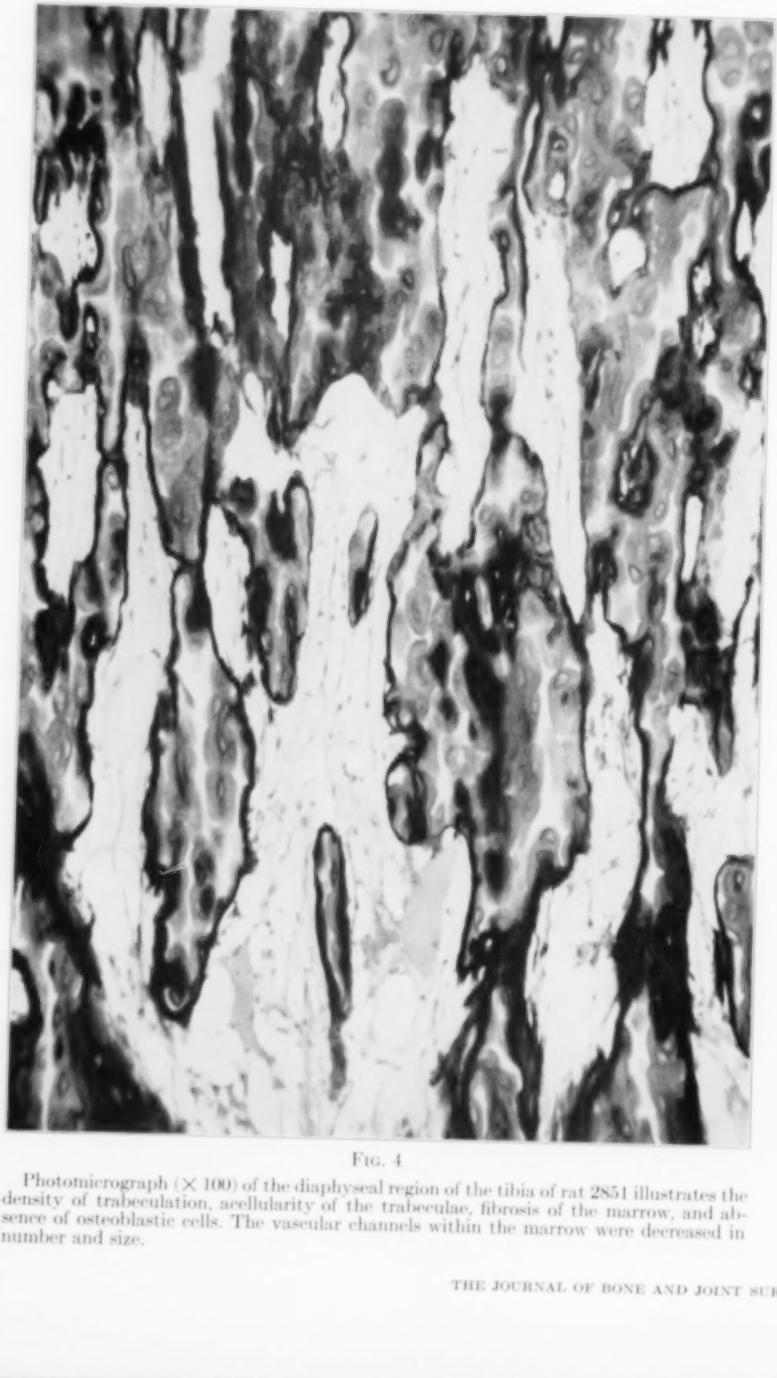


FIG. 4

Photomicrograph (× 100) of the diaphyseal region of the tibia of rat 2851 illustrates the density of trabeculation, acellularity of the trabeculae, fibrosis of the marrow, and absence of osteoblastic cells. The vascular channels within the marrow were decreased in number and size.

TABLE II

METABOLISM STUDY

Age, Body Weight, and Analysis of the Femur

| | | | Average Body Weight | | | Femur Analysis | | |
|---|---|---|---|---|---|---|---|---|
| Time (*Hours*) | No. of Rats | Age in Days (*Onset*) | Initial Weight (*Grams*) | Change (*Grams*) | Wet Weight (*Milligrams*) | Ash (*Per cent*) | Organic (*Per cent*) | Water (*Per cent*) |
| ¼ | 5 | 44–48 | 147 | 0 | 498 | 25.2 | 21.1 | 53.6 |
| ½ | 3 | 48–9 | 164 | 0 | 500 | 29.7 | 21.6 | 48.7 |
| 1 | 5 | 44–7 | 143 | 0 | 553 | 21.4 | 21.2 | 57.4 |
| 3 | 3 | 47–8 | 165 | – 6 | 524 | 27.9 | 21.8 | 49.6 |
| 6 | 6 | 44–7 | 150 | – 1 | 483 | 24.2 | 22.7 | 53.1 |
| 12 | 5 | 46 | 158 | – 1 | 505 | 25.5 | 22.7 | 52.0 |
| 24 | 4 | 48–9 | 152 | – 2 | 481 | 28.4 | 22.5 | 48.9 |
| 48 | 5 | 48–51 | 159 | – 8 | 528 | 27.4 | 23.9 | 48.7 |
| 72 | 3 | 54–5 | 139 | – 10 | 518 | 28.3 | 23.9 | 47.9 |
| 120 | 2 | 52 | 180 | – 33 | 591 | 26.8 | 25.1 | 48.2 |

weight (0.5 millicurie per milliliter of solution). The rats were divided into two groups, a preliminary Group I of eighteen and a subsequent Group II of twenty-three. Each rat in Group I was maintained in a stainless-steel metabolic cage. The rats in Group II were maintained in simple metabolism cages consisting of a two-liter beaker, with a three-eighths-inch mesh heavy screen floor and a sub-floor of ordinary wire screen to separate faeces from urine. A top for the beaker was made of the same material as the floor, and from it was suspended a wide-mouth two-ounce glass food jar containing about two days' food supply. A conventional water bottle was mounted on top of the cage. All animals were fed the standard laboratory diet and tap water *ad libitum*. Separate serial urine and faeces samples were collected and were ashed in nitric acid.

At autopsy, blood was collected directly from the heart in a serology tube and was allowed to clot. The gastro-intestinal tract was removed, and formed faeces were added to the faeces collected from each animal. A sample of skeletal muscle was removed, was weighed in a torsion balance, and was ashed in a weighed crucible for dry and ash weight determinations. The femur was removed and the remainder of the carcass was ashed in concentrated nitric acid. The procedures for analysis of the femur and the radioactivity determinations on the femur, serum, muscle, urine, faeces, and carcass were the same as those described previously.

## *Results*

### *Gross Changes*

The net changes in body weight between injection and autopsy are shown in Tabie II. The first marked change was a net loss of six grams at three hours, followed by lesser weight losses up to twenty-four hours. There was a net loss of eight to ten grams at two to three days, and thirty-three grams at five days.

In general appearance some of the rats were alert, but some were inactive. All were quiet for some hours following injection. Food consumption varied from normal to practically none. Water consumption appeared to be adequate, although not excessive. Fecal production ranged from normal to almost none. All animals survived the five-day experimental period.

### *Composition of the Femur*

A summary of the data on composition of the femur is given in Table II. The data appear to be within normal limits for rats forty to sixty days of age.

TABLE III-A

METABOLISM STUDY

Distribution of $Sr^{90}$ after a Single Intraperitoneal Injection †

| Time in Hours | Number of Rats | Estimated Serum | Femur | Percentage of Dose Retained<br>Estimated Skeleton | Estimated Muscle * | Carcass *** |
|---|---|---|---|---|---|---|
| ¼ | 5 | 2.83 ± .25 ** | 1.92 ± 0.20 | 38.4 ± 4.0 | 11.8 | 84.0 |
| ½ | 3 | 2.15 ± .36 | 2.60 ± 0.13 | 52.0 ± 2.7 | 10.8 | 83.7 |
| 1 | 5 | 0.513 ± 0.056 | 3.55 ± 0.03 | 71.0 ± 0.6 | 5.74 | 81.1 |
| 3 | 3 | 0.280 ± 0.011 | 4.01 ± 0.04 | 80.2 ± 0.8 | 4.21 | 87.3 |
| 6 | 6 | 0.101 ± 0.023 | 3.79 ± 0.29 | 75.8 ± 5.8 | 2.20 | 75.1 |
| 12 | 5 | 0.0680 ± 0.013 | 3.76 ± 0.41 | 75.2 ± 8.2 | 1.16 | 69.6 |
| 24 | 4 | 0.0475 ± 0.0063 | 3.96 ± 0.12 | 79.2 ± 2.4 | 0.78 | 77.8 |
| 48 | 5 | 0.0179 ± 0.0038 | 3.79 ± 0.31 | 75.8 ± 6.2 | 0.36 | 71.0 |
| 72 | 3 | | 4.28 ± 0.27 | 85.6 ± 5.4 | | 74.3 |
| 120 | 2 | | 4.31 ± 0.22 | 86.2 ± 4.4 | | 83.9 |

† There is some variability in the uptake of $Sr^{90}$ by different individuals. This is shown in Table III-A in which values for the femur and the skeleton are given as mean and standard errors for the groups. The values will vary with the age, the rapidity of growth of the particular species used, and the state of nutrition of the individual.

* Three animals only.

** Figures are mean and standard error.

*** Less one femur and gastro-intestinal tract.

TABLE III-B

METABOLISM STUDY

Excretion of $Sr^{90}$ after a Single Intraperitoneal Injection

| Time in Hours | Number of Rats | Urine | Percentage of Dose Excreted<br>Faeces * | Gastro-Intestinal Tract | Gastro-Intestinal Contents and Faeces * | Total Excreted |
|---|---|---|---|---|---|---|
| ¼ | 5 | 0.06 | 0.04 | 10.59 | 9.49 | 0.10 |
| ½ | 3 | 0.055 | 0.11 | 5.70 | 5.81 | 0.17 |
| 1 | 5 | 1.76 | 0.15 | 4.13 | 4.43 | 1.91 |
| 3 | 3 | 3.75 | 0.37 | 4.14 | 4.50 | 4.12 |
| 6 | 6 | 9.33 | 1.44 | 4.41 | 6.67 | 10.77 |
| 12 | 5 | 15.6 | 5.67 | 3.01 | 7.51 | 21.27 |
| 24 | 4 | 7.36 | 7.97 | 1.74 | 9.64 | 15.33 |
| 48 | 5 | 8.61 | 5.78 | 2.83 | 7.92 | 14.39 |
| 72 | 3 | 10.25 | | | 9.31 | 19.6 |
| 120 | 2 | 3.50 | | | 7.96 | 11.5 |

* Three animals only.

*Distribution of $Sr^{90}$*

*Carcass:* The $Sr^{90}$ remaining in the carcass averaged between 70 to 85 per cent of the injected dose, as shown in Table III-A. The general trend was slightly downward

*Serum:* The percentage of the injected dose of $Sr^{90}$ present in the serum was estimated from the sample by assuming the total serum to equal 2.4 per cent of the body weight[2]. The values derived are shown in Table III-A and Chart II. The serum level reached the highest value observed, 2.8 per cent of the injected dose, at fifteen minutes, and then declined to 0.5 per cent at one hour, 0.1 per cent at six hours, 0.05 per cent at twenty-four hours, and 0.02 per cent at forty-eight hours.

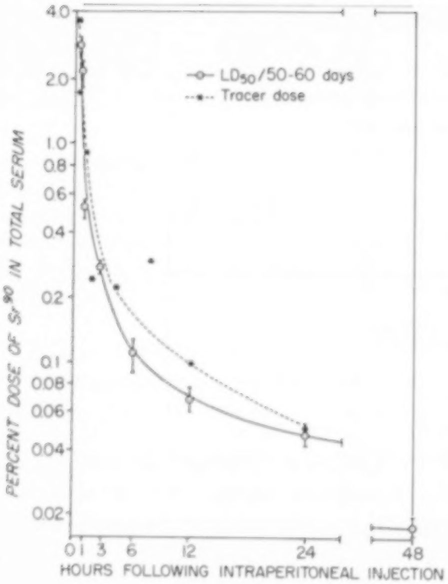


Chart II

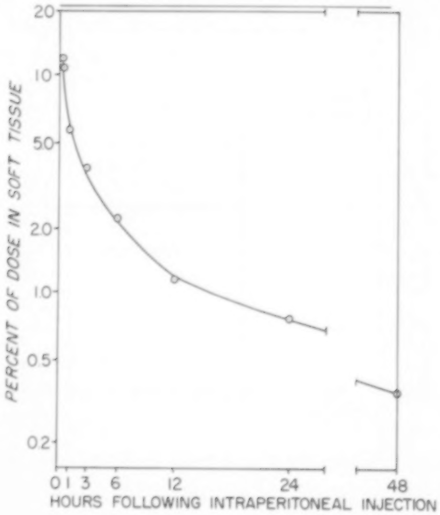


Chart III

Chart II: Percentage of injected dose of Sr 90 estimated to be present in total serum. Data from twenty-four rats.

Chart III: Percentage of injected dose of Sr 90 estimated to be present in soft tissue. Data from twenty-four rats.

*Muscle:* The percentage of injected dose in the total body musculature was calculated from the muscle sample, assuming the total muscle mass to equal 32.5 per cent of the body weight[9]. The values found are shown in Table III-A and Chart III. The amount of Sr 90 present in the muscle apparently followed the serum levels, but declined more slowly —from 12 per cent at fifteen minutes to 0.4 per cent at forty-eight hours.

*Femur and Skeleton:* The amount of Sr 90 remaining in the total carcass may be divided roughly between the percentage in the soft tissues and the percentage remaining in the skeleton. In order to calculate these percentages, the amount of strontium present in a muscle sample was used to calculate the percentage in the soft tissues, as already described; and the percentage of the injected dose in the femur was used to calculate the total percentage in the skeleton. The percentage of the dose of Sr 90 in the total body musculature was subtracted from the sum of the percentage of the injected dose found in the carcass plus that in the femur (which had been removed at autopsy) to give a rough estimate of the percentage of the injected dose in the skeleton. The ratio of the observed percentage of the dose of Sr 90 in the femur to this rough estimate of the percentage of the dose in the total skeleton was calculated for each animal $\left(\frac{\text{Percentage of dose found in femur}}{\text{Estimated percentage of dose in skeleton}}\right)$. The values of this ratio ranged between 0.02 and 0.04 fifteen to thirty minutes after injection; 0.045 and 0.06 one to forty-eight hours after injection; the average value was 0.05. This figure, representing the ratio of the percentage of the injected dose of Sr 90 contained in the femur as determined by actual count to the percentage of the injected dose estimated for the total skeleton, was used to determine the total skeletal retention of Sr 90 from the observed content of the femur (the values in Table III-A under the heading "Estimated Skeleton" were therefore obtained by dividing the values given under the heading "Femur" by 0.05). This method had previously been used by Jones and Copp.

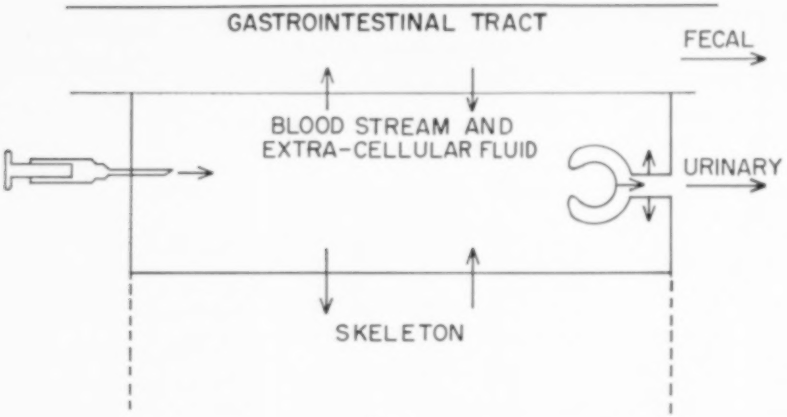

GASTROINTESTINAL TRACT
FECAL
BLOOD STREAM AND
EXTRA-CELLULAR FLUID
URINARY
SKELETON

Fig. 5

Schematic representation of metabolic pathway of Sr $^{90}$ after a single intraperitoneal injection.

*Gastro-intestinal tract and contents:* The distribution of Sr $^{90}$ in the gastro-intestinal tract was similar to that in the serum and body musculature (Table III-A). The gastro-intestinal content was especially high during the first hour but declined by an amount corresponding to the percentage in the faeces during the first twenty-four hours. The tract contained about 2 per cent of the injected dose at forty-eight hours.

*Excretion:* The urine accounted for over half of the excreted isotope, as shown in

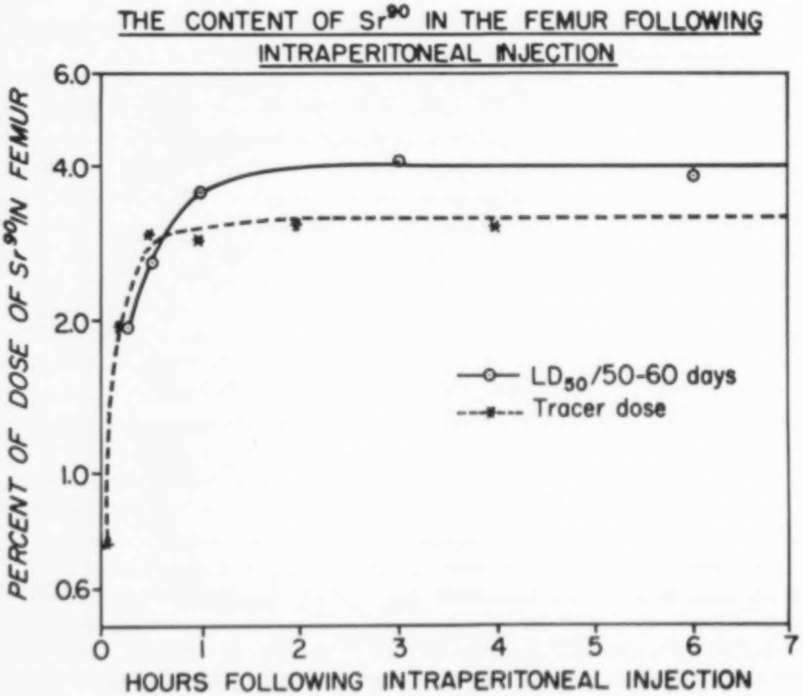


Chart IV

Observed percentage of injected dose of Sr $^{90}$ in left femur. Data from twenty-two rats.

Table III-B. Up to 15 per cent of the dose was removed by this route during the first twenty-four hours in several of the rats. Fecal excretion of Sr $^{90}$ generally lagged behind the urinary excretion both in time and quantity, but represented an important fraction of the total, up to 8 per cent of the injected dose being excreted by way of the faeces during the first twenty-four hours.

## DISCUSSION

The metabolism of Sr $^{90}$ probably parallels that of calcium [9, 21] and may be illustrated in a general way by the diagram Figure 5. A graphic summary of the actual distribution pattern following a single intraperitoneal injection of Sr $^{90}$ is shown in Chart V.

As can be seen from Charts II and V, Sr $^{90}$ was rapidly absorbed from the peritoneal cavity into the blood stream, reaching a peak serum level within fifteen minutes following injection. The serum level then decreased gradually to a plateau at around 0.02 per cent of the injected dose after forty-eight hours. Maximum absorption from the peritoneal cavity, therefore, occurred during the first hour.

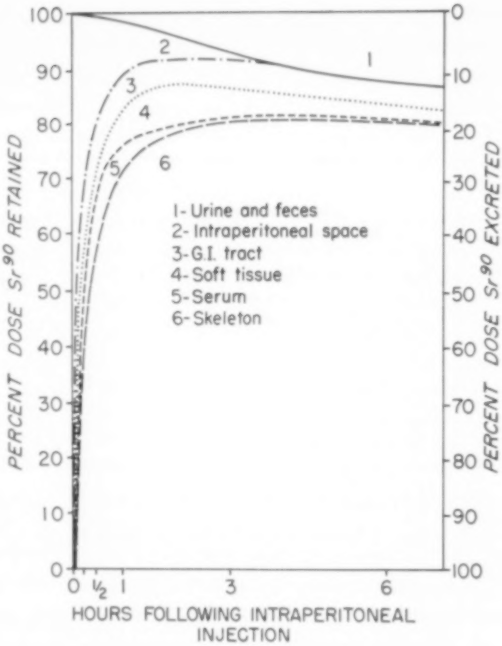


CHART V

Distribution of Sr $^{90}$ after a single intraperitoneal injection. Summary of data from sixteen rats.

Although a measurable fraction of the injected dose was excreted by way of the intestinal tract, the high content of the tract during the first thirty minutes may have been due to isotope still present in the peritoneal cavity on the outer surface of the intestine. In order to avoid this error, an attempt was made to inject into the space between the liver and the diaphragm in the fifteen-minute and the thirty-minute experimental groups. However, after one hour the error appeared to be unimportant, the majority of the dose having been distributed to the skeleton and soft tissues. Sr $^{90}$ present in the gastro-intestinal tract after one hour, therefore, probably was derived from the blood stream, gastro-intestinal digestive juices, or by direct diffusion from the peritoneal cavity. Radiation damage to the intestinal tract at levels comparable to those employed in this experiment has been described by Pierce.

The average urinary excretion was approximately 15 per cent of the injected dose within twelve hours. From the data of Jones and Copp and that of Bauer and his associates it would seem that the activity excreted by way of the kidneys is about the same or less than that excreted by way of the intestinal tract at trace levels. In this investigation there were frequent instances in which the percentage of the dose found in the urine far exceeded that found in the faeces, and in view of demonstrable kidney damage at higher doses it seems plausible that there was some kidney damage. However, Bloom did not observe histological changes in the kidneys of rats, mice, rabbits, or guinea pigs from either external or internal radiation in doses of $LD_{50}/30$.

Uptake of Sr $^{90}$ by the skeleton was extremely rapid, but subsequent mobilization was very gradual. The rate of mobilization, however, may have been decreased by irradiation damage to the bone [18].

One factor of importance in mobilization of inorganic salts from the skeleton appears to be the viability of the cellular elements; another is the state of the skeletal circulatory system.[18] Histological changes in both the vascular system and in the cellular elements of the bone were found at the level of $Sr^{90}$ employed in this experiment. There were fibrosis of the marrow, a notable absence of vascular channels in the diaphysis, and hemorrhages in the metaphyseal region.

In order to compare metabolism of $Sr^{90}$ at the high levels of beta irradiation used in this experiment with the metabolism at trace levels as reported by Jones and Copp, we have resorted to an analytical mathematical method described by Flexner and his associates, Thomas and his associates and Siri. In a steady state system (for example, the serum or the skeleton) in which simultaneous metabolic processes are occurring, the values for the concentration of a metabolite may be plotted on semi-log paper against a linear time axis, and, assuming that the separate processes are irreversible first order reactions, the separate components of the resultant curve may be subtracted out as individual straight lines. The sum of these straight lines, or the curve, can be described by the following general expression:

I. $C(t) = \Sigma_n A_i e^{-b_i t}$

where $C(t)$ represents the concentration of the metabolite as it varies with time, $A_i$ the quantity ("compartment factor") changing at a constant rate ($b_i$). $A_i$ is obtained from the analyzed curve by extrapolating the straight line to zero time, and $b_i$ is obtained from the observed half times, since $b_i$ equals $0.693/T\frac{1}{2}$. For a more detailed description of the method, the reader is referred to Siri and to Flexner and his associates.

The log of the serum concentrations for $Sr^{90}$ at the $LD_{50}/50\text{–}60$ are shown plotted as a function of time in Chart II, the solid line representing the estimated "best fit" for the observed data. Analysis of the curve according to the method described above gives an equation of at least three components:

II. $C(t) = 4.6e^{-4.3t} + 0.76e^{-0.55t} + 0.10e^{-0.034t}$

A similar analysis of the data for trace levels of $Sr^{90}$ reported by Jones and Copp[13] yields the following equation *:

III. $C(t) = 4.7e^{-2.2t} + 0.19e^{-0.39t} + 0.24e^{-0.62t}$

In a similar fashion, data obtained for the femur yielded the following equations:

IV. $F(t) = 4(1 - e^{-2.3t})$ ($LD_{50}/50\text{–}60$ days)

V. $F(t) = 3.2(1 - e^{-3.9t})$ (Tracer dose)

Both rate constants ($-2.3$ and $-3.9$) are of the same order of magnitude as those in the first term in equations II and III, suggesting that this term represents the net rate of skeletal uptake and that there is very little difference between the rate of uptake of $Sr^{90}$ at high and low levels of irradiation during the first seventy-two hours following injection. The "half-time" for deposition of the isotope in bone is between 0.16 and 0.30 hours for high levels of irradiation (equations II and IV), and 0.18 and 0.32 hours for tracer levels (equations III and V). These values are comparable within the limits of the experimental error and indicate that thirty minutes following injection at least one-half of the total quantity of isotope to be deposited is already present in the skeleton.

The data for the values obtained from analysis of the muscle have been analyzed in the same fashion, and the rate of loss of $Sr^{90}$ during the first seventy-two hours can be described by the following equation:

VI. $M(t) = 8.3e^{-0.41t} + 1.7e^{-0.033t}$

These rate constants are in good agreement with the rate constants of the last two terms in equation II, and the "compartment factors" when adjusted for weight differences** are also in close agreement.

---

* It should be emphasized that these and subsequent equations represent only the probable order of magnitude of composite rate constants and "compartment factors" because of the limited number of observations and the magnitude of the experimental errors involved.

** Multiplication of equation VI by the ratio: total weight of blood to total weight of muscle in a rat, about 0.074[10].

The last two terms in equations II and III may represent the composite rate of excretion, and the resultant of the rates of recirculation and redeposition of the isotope. If such is the case, then the excretion data expressed in terms of equation I should contain at least one rate comparable with a rate in equation II. The development of an excretion equation requires the assumption of a value for cumulative excretion over a period of at least one month, hence data from the toxicity studies as well as the metabolic studies were used. Analysis of these data gives the following equation:

$$\text{VII.}\quad E(t) = 15e^{-0.14t} + 7.8e^{-0.029t} + 15e^{-0.0047t} + 62e^{-0.0002t}$$

The value of $b_2$ in equation VII compares well with $b_3$ in equation II, but $b_1$ in equation VII has no counterpart in the blood equation. In view of the relatively large errors in the data from the toxicity studies and the few animals studied, the lack of agreement between equations II and VII is not considered significant. Experiments are currently in progress to obtain more precise measurements of excretory rates over a sixty-day interval.

The foregoing calculations reveal that the results obtained in this experiment with relatively high levels of radioactivity followed those at trace levels reported by Jones and Copp. The slightly lower serum level of the isotope (Chart II), the slight increase in deposition in the femur (Chart IV), and the increase in urinary excretion of the isotope at the dose levels of $Sr^{90}$ used in this study, although of doubtful statistical significance, still suggest the possibility of early radiation damage to metabolic processes. As will be shown in experiments to be reported subsequently, the damage induced by high levels of radiation becomes more apparent over longer periods of time.

## SUMMARY AND CONCLUSIONS

1. The $MLD_{50}/50$ for $Sr^{90}$ in young Long-Evans rats was estimated to be 2.5 to 3.0 microcuries per gram of body weight. In rats which survived for fifty days, the histological changes in the tibia consisted in disruption of the epiphyseal line, osteosclerosis, aseptic necrosis of the trabecular bone, and depression of the myeloid elements.

2. The metabolism of $Sr^{90}$ following intraperitoneal injection of an $MLD_{50}/50$ dose was found similar to that for $Sr^{89}$, $Sr^{90}$, and $Ca^{45}$ in tracer doses as reported by other authors. $Sr^{90}$ was quickly absorbed from the peritoneal cavity into the blood stream, and, at first, was distributed in part to the soft tissues; by the end of one to three hours, however, 75 to 80 per cent of the injected dose had been deposited in the skeleton. Up to 15 per cent of the injected isotope was excreted in the urine and up to 8 per cent in the faeces during the first twenty-four hours, urinary excretion being more variable than the fecal. Mobilization of the isotope from the skeleton was not appreciable during the five-day experimental period.

NOTE. The authors would like to express their deep appreciation to Mr. John H. Wolff for his help in the mathematical analysis of the data.

## REFERENCES

1. BARR, J. S.; LINGLEY, J. C.; and GALL, E. A.: Effect of Roentgen Irradiation on Epiphyseal Growth. Experimental Studies upon the Albino Rat. Am. J. Roentgenol., **49:** 104–115, 1943.
2. BAUER, G. C. H.; CARLSSON, A.; and LINDQUIST, B.: A Comparative Study on the Metabolism of $Sr^{89}$ and $Ca^{45}$. Acta Physiol. Scandinavica, in press.
3. BERLIN, N. I.; HUFF, R. L.; VAN DYKE, D. C.; and HENNESSY, T. G.: The Blood Volume of the Adult Rat, as Determined by $Fe^{59}$ and $P^{32}$ Labelled Red Cells. Proc. Soc. Exp. Biol. Med., **71:** 176–178, 1949.
4. BLOOM, W.: Histopathology of Irradiation from External and Internal Sources, Ch. 14. New York, McGraw-Hill, 1949.
5. BRUES, A. M.: Biological Hazards and Toxicity of Radioactive Isotopes. J. Clin. Invest., **28:** 1286–1296, 1949.
6. CARLSSON, A.: Metabolism of Radio Calcium in Relation to Calcium Intake in Young Rats. Acta Pharmacol. et Toxicol., **7** (Supplementum): 1–74, 1951.
7. CARLSSON, A.; LINDQUIST, M.; and MAGNUSSON, F.: On the Mechanism of Skeletal Turnover of Lime Salts. Acta Physiol. Scandinavica, **26:** 200–211, 1952.

8. Copeland, M. M.: The Effect of Ionizing Radiations on Bone (Other Than Marrow), and Striated Muscle. *In* Instructional Course Lectures, Vol. 10, The American Academy of Orthopaedic Surgeons, 1953. Ann Arbor, J. W. Edwards, 1953.
9. Copp, D. H.; Hamilton, J. G.; Jones, D. C.; Thomson, D. M.; and Cramer, C. F.: The Effect of Age and Low Phosphorus Rickets on Calcification and the Deposition of Certain Radioactive Metals in Bone. *In* Metabolic Interrelations. Transactions of the Third Conference on Metabolic Interrelations, New York, Josiah Macy, Jr. Foundation, 1951.
10. Donaldson, H. H.: The Rat. Mem. Wistor Institute of Anat. and Biol. 1924.
11. Evans, R. D.; Harris, R. S.; and Bunker, J. W. M.: Radium Metabolism in Rats, and the Production of Osteogenic Sarcoma by Experimental Radium Poisoning. Am. J. Roentgenol., **52:** 353–373, 1944.
12. Flexner, L. B.; Cowie, D. B.; and Vosburgh, G. H.: Studies on Capillary Permeability with Tracer Substances. Cold Spring Harbor Symp. Quant. Biol., **13:** 88–98, 1948.
13. Heller, M.: *In* Histopathology of Irradiation from External and Internal Sources, Ch. 5, by W. Bloom. New York, McGraw-Hill, 1948.
14. Jones, D. C., and Copp, D. H.: The Metabolism of Radioactive Strontium in Adult, Young, and Rachitic Rats. J. Biol. Chem., **189:** 509–514, 1951.
15. Lonti, P.: Comment se distribue dans le squelette le radiocalcium administré au lapin adulte. Rev. Belge Pathol. et Méd. Expér., **23:** 118–125, 1953.
16. Norris, W. P., and Kisieleski, W.: Comparative Metabolism of Radium, Strontium, and Calcium. Cold Spring Harbor Symp. Quant. Biol. **13:** 164-172, 1948.
17. Pecher, C.: Biological Investigations with Radioactive Calcium and Strontium. Proc. Soc. Exper. Biol. and Med., **46:** 86–91, 1941.
18. Pierce, M.: The Gastrointestinal Tract. *In* Histopathology of Irradiation from External and Internal Sources by W. Bloom. New York, McGraw-Hill, 1948.
19. Ray, R. D.; LaViolette, D. F.; Buckley, H. D.; and Mosiman, R. S.: Studies of Bone Metabolism. I. A Comparsion of the Metabolism of $Sr^{90}$ in Living and Dead Bone. J. Bone and Joint Surg., **37-A:** 143–155, Jan. 1955.
20. Reidy, J. A.; Lingley, J. R.; Gall, E. A.; and Barr, J. S.: The Effect of Irradiation on Epiphyseal Growth. II. Experimental Studies upon the Dog. J. Bone and Joint Surg., **29:** 853–873, Oct. 1947.
21. Shorr, E., and Carter, A. E.: Usefulness of Strontium as an Adjuvant to Calcium in Remineralizing the Skeleton in Man. Bull. Hosp. Joint Dis., **13:** 59–66, 1952.
22. Singer, L.; Armstrong, W. D.; and Premer, M. L.: Skeletal Calcium Turnover in Non-Growing Rats. Proc. Soc. Exp. Biol. and Med., **80:** 643–646, 1952.
23. Siri, W. S.: Isotopic Tracers and Nuclear Radiations with Applications to Biology and Medicine, pp. 392–402. New York, McGraw-Hill, 1949.
24. Thomas, R. O.; Litovitz, T. A.; Rubin, M. L.; and Geschickler, C. F.: Dynamics of Calcium Metabolism, Time Distribution of Intravenously Administered Calcium. Am. J. Physiol., **169:** 568–575, 1952.

# LATE EFFECTS (TWENTY-FIVE TO FORTY YEARS) OF THE EARLY MEDICAL AND INDUSTRIAL USE OF RADIOACTIVE MATERIALS

## Their Relation to the More Accurate Establishment of Maximum Permissible Amounts of Radioactive Elements in the Body

## Part II*

BY LIEUTENANT W. B. LOONEY, *Medical Corps, United States Naval Reserve*

*From the United States Naval Hospital, National Naval Medical Center, Bethesda, Maryland*

### ROENTGENOGRAPHIC CHANGE

Skeletal roentgenographic changes have been one of the most significant clinical findings in these investigations[2,17]. Areas of increased density have been found in cancellous bone on skeletal roentgenographic examination. This roentgenographic change is the result of a typical osseous tissue in the trabecular spaces; infrequently it is the result of hyperplasia of trabeculae. Well defined areas of decreased density were found in compact bone. These were the result of the destructive changes in the cortex of the bone.

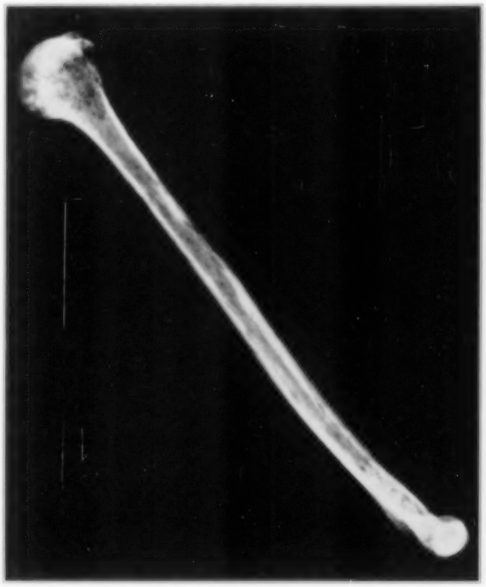


FIG. 1

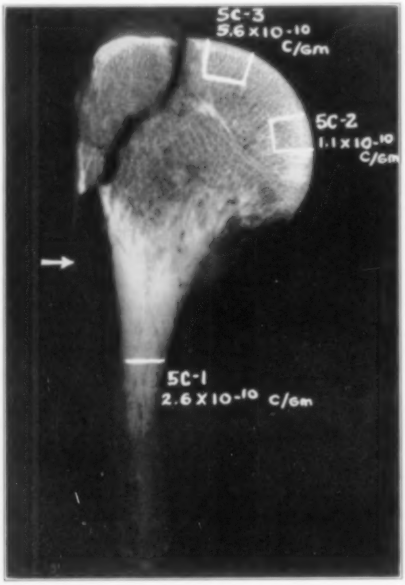


FIG. 2

Fig. 1: Roentgenogram of the humerus taken from patient M. K. at autopsy. Note the areas of increased density in the head of the humerus and the small areas of decreased density in the cortex of the shaft. (Courtesy, Dr. A. M. Brues, Division of Biological and Medical Research, Argonne National Laboratory.)

Fig. 2: Roentgenogram of a two-millimeter section taken from the head of the right humerus (Fig. 3, Part I). Sections of bone, *5C-2* and *5C-3*, were removed following the making of gross autoradiographs of this bone section. As will be noted in the figure, *5C-2* was taken from an area which seemed to have a large concentration of radium as shown by gross autoradiography (see Figs. 1, 2, and 3, Part I). *5C-3* was taken from an area which seemed to have a small amount of radium as shown by gross autoradiography and a normal roentgenographic pattern. It should be noted that the radium content in *5C-3* was five times the content in *5C-2*. Radium values are expressed as curies per gram of ashed bone. (Courtesy Dr. A. M. Brues, Division of Biological and Medical Research, Argonne National Laboratory.)

---

* This is the second of a series of three articles in a thoroughgoing analysis of the late effects of the use of radioactive materials. The first of the series appeared in the December issue of *The Journal* (pages 1169–1187); the third and last will appear in the April issue. It is suggested, in order that the reader may gain the full significance of this report, that he read Part I.

## TABLE I

### Radium Patients

| Chicago Group | | | | | Boston Group | | | |
|---|---|---|---|---|---|---|---|---|
| Symbol for Patient Chicago Report ** | Patient's Initials | Retained Radium (µg) | Manner Selected | No. for Patient in This Report | No. for Patient Boston Report * | Patient's Initials | Retained Radium (µg) | Manner Selected |
| 115 | Q. Q. | 0.01 | N. S. (by name) | 1 | | | | |
| | | | | 2 | 30 | R. L. | 0.02 | N. S. (inhaled radium) |
| 109 | M. H. | 0.06 | N. S. (bleeding tendencies familial) | 3 | | | | |
| C | C. C. | 0.4 | N. S. (name on list) | 4 | | | | |
| | | | | 5 | 28 | S. L. | 0.4 | N. S. (radium chemist) |
| | | | | 6 | 29 | G. P. | 0.4 | N. S. (physicist) |
| Paul N. | P. N. | 0.5 | N. S. (name on list) | 7 | | | | |
| 117 | R. W. | 0.5 | N. S. (name from physician) | 8 | | | | |
| B | O. W. | 0.5 | N. S. (name on list) | 9 | | | | |
| 101 | A. B. | 0.5 | N. S. (name on list) | 10 | | | | |
| S | L. P. | 0.6 | N. S. (name on list) | 11 | | | | |
| U | R. M. | 0.6 | N. S. (name on list) | 12 | | | | |
| 116 | H. V. | 0.7 | Sym. (pain in hip) | 13 | | | | |
| I | E. A. | 0.8 | N. S. (name on list) | 14 | | | | |
| Q | C. D. | 0.8 | N. S. (name on list) | 15 | | | | |
| Edith C. | E. J. | 0.8 | N. S. (name on list) | 16 | | | | |
| | | | | 17 | 25 | M. B. | 0.8 | Sym. (pain in hips) |
| 105 | Mrs. A. DeR. | 0.86 | Sym. (tibia-related to Ra through husband) | 18 | | | | |
| K | G. Z. | 0.9 | N. S. (name on list) | 19 | | | | |
| O | G. N. | 1.0 | N. S. (name on list) | 20 | | | | |
| T | D. D. | 1.0 | N. S. (name on list) | 21 | | | | |
| J | V. McC. | 1.0 | N. S. (name on list) | 22 | | | | |
| 113 | G. L. | 1.1 | N. S. (name from physician) | 23 | | | | |
| 112 | M. K. | 1.3 | Sym. (pain in foot) | 24 | | | | |
| | | | | 25 | 20 | A. W. | 1.5 | N. S. (name) |
| 102 | W. B. | 1.6 | Sym. (non-union, mandible) | 26 | | | | |
| 114 | M. M. | 1.6 | Sym. (pink tooth) | 27 | | | | |
| A | C. S. | 1.6 | N. S. (name on list) | 28 | | | | |
| N | A. M. | 1.8 | N. S. (name on list) | 29 | | | | |
| Rose D. | R. D. | 1.9 | N. S. (name on list) | 30 | | | | |
| P | L. W. | 2.6 | N. S. (name on list) | 31 | | | | |
| | | | | 32 | 18 | M. P. | 2.0 | N. S. (radium chemist) |
| E | F. P. | 2.6 | N. S. (name on list) | 33 | | | | |
| R | C. L. | 3.6 | N. S. (name on list) | 34 | | | | |
| 111 | J. J. | 4.2 | N. S. (name from physician) | 35 | | | | |
| | | | | 36 | 11 | C. I. | 6.0 | Sym. (chronic arthritis) |
| | | | | 37 | 12 | N. S. | 5.5 | Sym. (pain, hips and shoulders) |

TABLE I *(continued)*

| Chicago Group | | | | | Boston Group | | | |
|---|---|---|---|---|---|---|---|---|
| Symbol for Patient Chicago Report ** | Patient's Initials | Retained Radium (μg) | Manner Selected | No. for Patient in This Report | No. for Patient Boston Report * | Patient's Initials | Retained Radium (μg) | Manner Selected |
| 110 | F. J. | 5.4 | N. S. (by name) | 38 | | | | |
| 106 | D. DeR. | 5.6 | N. S. (name from physician) | 39 | | | | |
| L | D. A. | 6.7 | N. S. (name on list) | 40 | | | | |
| | | | | 41 | 10 | G. W. | 7.0 | Sym. (pain in jaw) |
| | | | | 42 | 4 | O. A. | 10.5 | Sym. (fracture, bone of foot) |
| K. B. | K. B. | 2 to 10 | Sym. (pain in hip) | 43 | | | | |
| 104 | A. DeR. | 10.7 | N. S. (name from physician) | 44 | | | | |
| | | | | 45 | 7 | F. W. | 9.0 | Sym. (pain in left arm) |
| | | | | 46 | | E. C. | 11.5 | Sym. (fractured spine) |
| 108 | M. H. | 11.3 | Sym. (pain in hips) | 47 | | | | |
| | | | | 48 | 3 | H. B. | 11.5 | N. S. (reported in literature) |
| 107 | J. F. | 13.9 | N. S. (name from physician) | 49 | | | | |
| | | | | 50 | 1 | M. H. | 23.0 | Sym. (difficulty, teeth and mandible) |

N. S. — not selected as a result of symptoms.
Sym. — selected as a result of symptoms.
*, ** references same as in Table II.
Patient 46 was omitted in the Boston report.
Patient 27 of the Boston report was omitted in this report.
Patients 33 and 47 were omitted in the Chicago report.
Patients 103, 117, and 119 of the Chicago report were omitted in this report.
The patients of the Elgin State Hospital are the same patients studied by Schlundt, Nerancy, and Morris. (Schlundt, H.; Nerancy, J. T.; and Morris, J. P.: Detection of Radium in Living Persons. IV. Retention of Soluble Radium Salts Administered Intravenously. Am. J. Roentgenol., **30**: 515–522, 1933.)

These changes were divided into three groups, principally on a descriptive basis[15,21]:

*Group I:* Areas of decreased density which were usually one to two millimeters in width and five to twenty millimeters in length in the long bones which gave a streaked appearance, and "punched-out" areas varying from two to twenty millimeters in the greatest dimensions present in the skull (Figs. 1, 4, 5, 6-A, 6-B, and 16).

*Group II:* Areas of increased density usually associated with areas of decreased density with varying degrees of change in the trabecular pattern. These usually occurred in the femoral head, the humeral head, and the glenoid process, giving a "mottled" or "moth-eaten" appearance (Figs. 1, 4, and 17). There was an increase in frequency of biconcavities and collapse of the vertebrae in patients having larger amounts of retained radium (Fig. 18). Areas of increased density were found along the superior and inferior borders as well as small areas of increased density in the vertebral bodies.

*Group III:* The term "aseptic necrosis" has been used in referring to the changes in normal configuration. The heads of the femora, the bones of the feet, and the mandible were most commonly involved (Figs. 6-B and 11).

Serial roentgenograms of a few of these patients over long periods of time have been obtained. In most of the available serial roentgenographic studies, changes were not found until years after the deposition of the radioactive element. Periods of skeletal change may

TABLE II

LUMINOUS DIAL WORKERS

| Chicago Group | | | | Boston Group | | | | |
|---|---|---|---|---|---|---|---|---|
| Symbol for Patient Chicago Report ** | Patient's Initials | Retained Radium ($\mu$g) | Manner Selected | No. for Patient in This Report | No. for Patient Boston Report * | Patient's Initials | Retained Radium ($\mu$g) | Manner Selected |
| 305 | A. H. | 0.02 | N. S. (by name) | 1 | | | | |
| 311 | P. T. | 0.06 | N. S. (by name) | 2 | | | | |
| 303 | E. H. | 0.1 | N. S. (by name) | 3 | | | | |
| 304 | L. H. | 0.2 | N. S. (by name) | 4 | | | | |
| 312 | A. T. | 0.25 | N. S. (by name) | 5 | | | | |
| 307 | D. L. | 0.34 | N. S. (by name) | 6 | | | | |
| 308 | E. O'S. | 0.4 | N. S. (by name) | 7 | | | | |
| 309 | C. P. | 0.5 | Sym. (arm removed) | 8 | | | | |
| | | | | 9 | 26 | H. V. | 0.7 | Sym. (losing teeth) |
| 306 | H. K. | 0.7 | N. S. (wanted Ra checked) | 10 | | | | |
| 310 | M. R. | 0.79 | N. S. (by name) | 11 | | | | |
| | | | | 12 | 24 | A. B. | 0.9 | Sym. (losing teeth) |
| 301 | J. B. | 1.2 | N. S. (by name) | 13 | | | | |
| 313 | R. W. | 1.3 | Sym. (fractured leg) | 14 | 23 | R. W. | 1.0 | Sym. (fractured leg) |
| | | | | 15 | 22 | F. C. | 1.0 | Sym. (losing teeth) |
| | | | | 16 | 19 | K. M. | 1.5 | Sym. (fractured mandible) |
| | | | | 17 | 21 | A. C. | 1.5 | N. S. |
| | | | | 18 | 17 | J. J. | 2.0 | N. S |
| | | | | 19 | 16 | K. W. | 2.5 | Sym. (pain in hips) |
| | | | | 20 | 14 | H. G. | 2.9 | Sym. (teeth and mandible) |
| 302 | I. D. | 3.8 | Sym. (pain in hips) | 21 | | | | |
| | | | | 22 | 13 | R. B. | 4.0 | Sym. (pain, hips and shoulders) |
| | | | | 23 | 9 | F. R. | 6.5 | Sym. (vague bone pain) |
| | | | | 24 | 8 | L. S. | 8.0 | Sym. (dental difficulty) |
| | | | | 25 | 6 | M. L. | 10.0 | Sym. (pain in hips) |
| | | | | 26 | 5 | M. F. | 10.0 | Sym. (pain, mandible) |
| 314 | M. L. | 10 | Sym. (fractured femur) | 27 | | | | |
| | | | | 28 | 2 | E. C. | 18.0 | Sym. (pain, right ankle) |

N. S. — not selected as a result of symptoms.
Sym. — selected as a result of symptoms.

* Aub, J. C.; Evans, R. D.; Hempelmann, L. H.; and Martland, H. S.: The Late Effects of Internally Deposited Radioactive Materials in Man. Medicine, **31:** 221–329, 1952.

** Looney, W. B.; Hasterlik, R. J.; Brues, A. M.; and Skirmont, E.: A Clinical Investigation of the Chronic Effects of Radium Salts Administered Therapeutically (1915–1940). Am. J. Roentgenol. and Rad. Therapy, **73:** 1006–1037, 1955.

Patients 4, 5, 6, 7, 11, 21, 27 were omitted in the Chicago report.
Patient 15 of the Boston report was omitted in this report.
Patients 18 and 26 received radium and mesothorium medically.

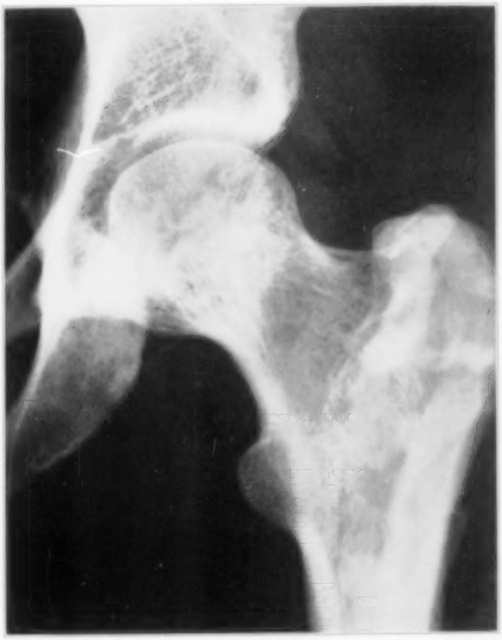


FIG. 3

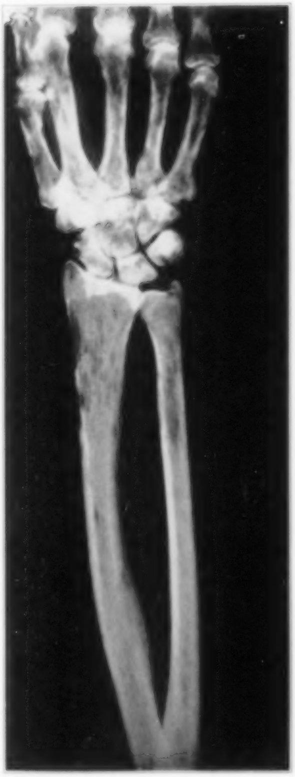


FIG. 4

Fig. 3: Roentgenogram of the head of the femur of patient C. L. (R-34). The mottled appearance is the result of the atypical osseous tissue and hypertrophy of the trabeculae and is characteristic of the changes seen in cancellous bone following the deposition of radioactive elements. (Review Figs. 3, 4, and 5, Part I.) (Courtesy, Dr. A. M. Brues, Division of Biological and Medical Research, Argonne National Laboratory.)

Fig. 4: Roentgenogram of the lower arm and hand of patient M. L. (L-27). The small areas of decreased density in the radius and ulna and bones of the hand give a streaked appearance. These small well differentiated areas of decreased density are characteristic of the deposition of radioactive elements. (Republished by permission from "The Initial and Industrial use of Radioactive Materials." W. B. Looney, *American Journal of Roentgenology, Radium Therapy, and Nuclear Medicine*, **72**:842, 1954.)

occur and may become stabilized or may improve. Later skeletal changes occur with increasing frequency.

For example, patient M. H. (R-50) was given radium in 1922 (age forty-two or forty-four)[1]. Ten years later, skeletal roentgenographic changes characteristic of radium deposition occurred primarily in the mandible. These changes gradually improved. In 1940 (age sixty), a significant increase in skeletal involvement occurred. There was a gradual increase in frequency and severity until her death in 1949 (Table III). Roentgenograms of the skull of patient M. K. (R-24) in 1948 demonstrated twelve areas of decreased density (Fig. 16-A). In 1951 (Fig. 16-B), the number of areas had increased to twenty-two; however, there was minimal increase in the size of the areas. The size of these areas usually did not become greater than dimensions given in the description of the roentgenographic findings. Infrequently, however, they may be as great as three to four centimeters in diameter. The usual sequence of events was an increase in number, as well as an increase in the number of bones involved.

It is evident from these and other serial roentgenograms that these changes do not become detectable until many years after the deposition of radioactive elements. The possibility of skeletal histopathological changes being produced and remaining undetected roentgenographically for years must also be considered. There were no roentgenographic changes found on complete skeletal roentgenographic examination of patient H. V.

TABLE III *

ROENTGENOGRAPHIC CHANGES IN PATIENT M. H. (R-50)

| Year | Mandible (*Side*) | | Glenoid Process | | Skull (*Side*) | | Humerus | | | Radius | | Ulna | | Vertebrae |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Head | | Shaft | | | | | |
| | R. | L. | R. | L. | R. | L. | R. | L. | | R. | L. | R. | L. | |
| 1933 | + + | + + + | + M | ?M | | | + M | ?M | | | | | | |
| 1934 | + + | + + + | | ?M | | | | | | | | | | |
| 1936 | + | + + | | | | | | | | | | | | |
| 1937 | + | + | + M | ?M | | | + M | + M | | | | | | |
| 1938 | | | | | | | | | | | | | | |
| 1939 | | | | | | | | | | | | | | |
| 1940 | + | + | + M | ?M | ? | ? | + M | + M | | + S | + S | Neg. | | |
| 1942 | | | | | | | | | | | | | | + + C-L-4 |
| 1943 | | | | | | | | | | + S | + S | Neg. | | |
| 1944 | | | + M | ?M | | | + M | + M | | + S | + S | Neg. | | |
| 1945 | | | | | | | | | | + + S<br>Head | + S | ?S | ?S | + + C-L-4 |
| 1946 | | | | | | | | | | | ?S | | | |
| 1947 | | | + + M | | | | + + + M | + M | | | | | | |
| 1948 | | | | | | | | | Neg. | | | | | |
| 1949 | | | | | | | | | + S | + S<br>+ AN | + S | | | + + + C-L-4<br>+ + C-L-3<br>5–10 I-T-10 and 11. |

*I. *Severity of the roentgenographic changes:* These were placed in five categories: ?, +, + +, + + +, and + + + +. The question mark denotes questionable alteration from the normal pattern, + + + + being the most severe changes noted.

II. *Symbols used for denoting roentgenographic changes:*

A. M—areas of increased density usually associated with varying degrees of decreased density and change in normal trabecular pattern. Changes give a "mottled" or "moth-eaten" appearance.

B. D-1, D-2, etc.—Well differentiated areas of decreased density one to four millimeters in diameter. Usually if there are more than three areas the graduation system described in I was used.

TABLE III

Roentgenographic Changes in Patient M. H. (R-50)

| Femur |  |  |  |  |  |  |  |  |  |
|---|---|---|---|---|---|---|---|---|---|
| Head |  | Shaft |  | Tibia |  | Fibula |  | Bones of Feet | Misc. |
| R. | L. | R. | L. | R. | L. | R. | L. |  |  |
|  | ?M |  |  | Neg. |  | Neg. |  |  |  |
|  | ?M |  |  | Neg. |  | Neg. |  |  | + Iliac crests and L. sym. pubis. |
| ?M | ?M |  |  |  |  |  |  |  | + Iliac crests and inf. rami of pubis. Protrusion right acetabulum. |
| + M | + M |  |  |  |  |  |  | Healed fracture 1st, 2nd, and 3rd metatarsals. Fracture of the 4th. | + Sacro-iliac joints. |
| + M | + M | + S |  |  |  | + S | ?S |  | Protrusion acetabula. + + I around right acetabular roof. |
| + + M<br>+ AN | + M | + S | + S | + S | + S | + S | + S |  | Same except + + I around inf. rami of pubis. |
| + + M<br>+ AN | + + M | + + S | + S | + S | + + S | + S | + S |  | Greater around acetabula + + + I. |
| + + + M<br>+ + AN | + + + M | + + S | + S | + S | + + + S | + S | + + S |  | No change. |
| + + + M<br>+ + AN | + + + M | + + S | + S | + S |  |  |  |  | + I sacro-iliac joints. |
|  |  | + + S | + S | + S | + + + S | + S | + + S | + S 1st metatarsals, fracture of 5th. | + I sacro-iliac joints. |
| + + + M<br>+ + AN | + + + M | + S | + S |  |  |  |  | Fracture still present, no callus. | + I sacro-iliac joints. |
| + + + + M<br>+ + AN | + + + + M |  |  |  |  |  |  | + S 1st metatarsals healed fracture. | + I sacro-iliac joints. |
|  |  |  |  |  |  |  |  |  | + S Anterior Segment of right lower ribs. |

1. 10D-1—One area of decreased density ten millimeters in greatest diameter.

2. 5X5D-2—Two areas of decreased density approximately five by five millimeters in size.

C. I-1, I-2, 10I-1, 5X5I-2—Denotes areas of increased density instead of decreased density.

D. S—Over 6-0 longitudinal areas of decreased density usually one to two millimeters in width and five to ten millimeters in length with a "streaked" appearance were graded by the method described (I).

E. AN—These are bone changes compatible with the diagnosis of aseptic necrosis.

F. C—Biconcavities of the vertebrae. G. O—Missing. H. Inc.—Incomplete.

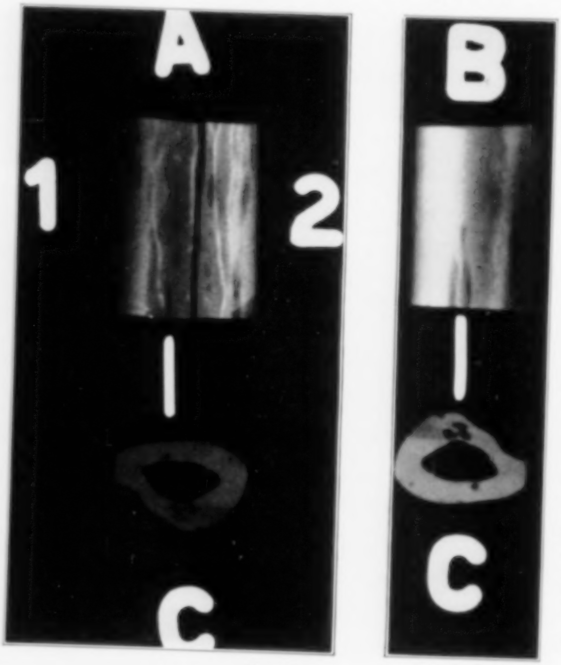


FIG. 5

Fig. 5: Roentgenograms of horizontal and vertical sections of the fibula of patient M. K. (R-24). Note the "streaked" areas that are seen in the long bones as the result of well differentiated areas of destruction in the cortex. The pointers show the areas of destruction in the vertical and horizontal planes. (Argonne National Laboratory Report, ANL 4666.)

(R-13) * in 1950, with the exception of an aseptic necrosis of the right femoral head. However, minor histopathological changes characteristic of the deposition of radioactive elements were found in sections of the left fibula of this patient. In 1954, roentgenographic changes characteristic of the deposition of radioactive elements were present in the fibula and other long bones [9].

It has been shown that skeletal histopathological changes [4] are reversible in animals following the deposition of radioactive elements. The history of patient M. H. (R-50) demonstrates that skeletal changes as seen by roentgenogram are reversible in man following the deposition of radioactive elements. It is reasonable to assume, therefore, that reversible skeletal histopathological changes occur in man, as well as in animals, following the deposition of radioactive elements. When the reparative processes are able to be maintained at a level equal to the destructive processes, no detectable changes occur as seen by roentgenogram. If the ability to maintain skeletal repair is impaired or decreased, more and more permanent alterations probably result from the imbalance between the reparative and destructive processes.

Histopathological changes have been present to such a degree that roentgenographic changes have been found in many patients who are symptom-free. However, significant clinical changes usually do not occur in the absence of skeletal roentgenographic change. The results of skeletal roentgenographic, autoradiographic, and histopathological studies on serial bone sections [2,16] indicate that repeated skeletal roentgenographic examinations are the most satisfactory clinical method for the early detection of skeletal alterations following the deposition of radioactive elements (Part I: Review Figs. 1, 2, 3, 4, 5, and 6).

Because of recent interest in the relative effects of radium and mesothorium in the eventual production of clinical changes, all of the roentgenographic and clinical changes that were present in the luminous-dial workers and individuals who had received radium medically were tabulated and arranged in order of increasing amounts of retained radium (Tables IV and V). The mean age of the twenty-eight luminous-dial workers at the time of employment was 21.4 years and the mean time of retention 26.5 years. The mean age for the patients who had received radium was 34.8 years and the mean time of retention 21.4 years.

The roentgenographic findings in all of the luminous-dial workers and patients who had been given radium and who had complete skeletal roentgenographic examinations in the Chicago and Boston investigations were tabulated in a manner similar to that in

---

* The symbol H.V. (R-13) denotes the patient's initials and the patient's number in the tables summarizing the Boston and Chicago investigations. R denotes that the patient received radium medically. See Tables I, IV, and VI.

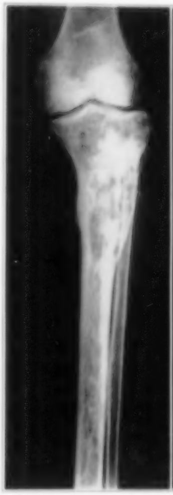


FIG. 6-A

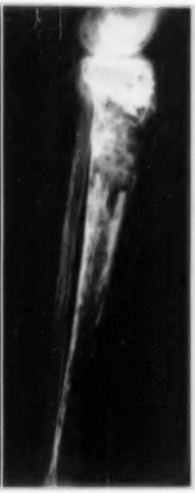


FIG. 6-B

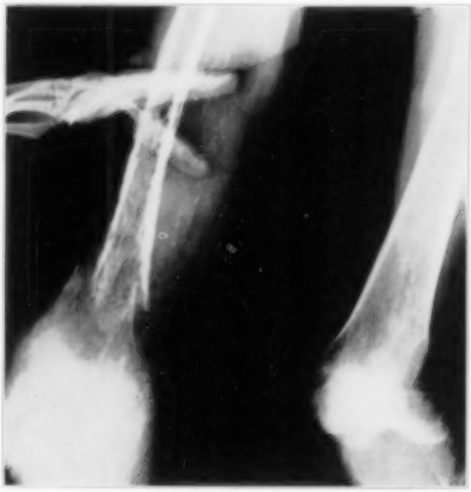


FIG. 7

Fig. 6-A: Roentgenogram of the right tibia of Mrs. A. DeR. (R-18) made in 1947 following x-ray therapy and biopsy. Note the area of increased density just superior to the site of biopsy and the small areas of decreased density in the lower end of the shaft. (Courtesy, Dr. E. H. Fell, Presbyterian Hospital, Chicago, Illinois.)

Fig. 6-B: This is a lateral view of the tibia and fibula of Mrs. A. DeR. (R-18) made in 1948. Note the increase in destruction and the "streaking" in the lower shaft. (Courtesy, Dr. E. H. Fell, Presbyterian Hospital, Chicago, Illinois.)

Fig. 7: Roentgenograms (anteroposterior and lateral) of the right femur made in 1949, immediately after the pathological fracture, patient, Mrs. A. DeR. (R-18). (Courtesy, Dr. E. H. Fell, Presbyterian Hospital, Chicago, Illinois.)

Tables IV and V (Tables VI and VII). It should be noted that relatively few roentgenographic changes or symptoms were present in any patient in either of the two groups who had less than .5 microgram of radium in the body. From about .5 to .9 microgram of retained radium, the roentgenographic changes and symptoms begin to occur with increasing frequency; the clinical changes increase significantly in patients having over one microgram of radium in both series. No difference can be detected in either the roentgenographic changes or symptoms of the luminous-dial workers and the patients who had been given radium with comparable amounts of radium in their bodies even though a significant difference in age (21.4 years for luminous-dial workers in contrast with 34.8 years for the patients who had been given radium) exists.

## TUMOR FORMATION

The clinical course of patients in whom malignant tumors eventually develop is illustrated in the following case histories.

Patient I. D. (L-21) began to have symptoms as a result of skeletal changes eleven years after employment as a luminous-dial worker in 1934[5]. Several skeletal lesions occurred over a period of years following the deposition of the radioactive element. A biopsy specimen was taken from the left femur in 1950, following the clinical diagnosis of chronic osteomyelitis. The histological diagnosis at that time was a low-grade inactive fibrous osteomyelitis associated with recent slow-growing cancellous type of fibrous osteoma[22]. In 1952, pain began to occur and to increase in frequency in the left femur, and the roentgenograms were interpreted as being suggestive of malignant changes in the medial condyle. The extremity was amputated and an osteogenic sarcoma was found throughout the femur on histological examination[3]. The patient died a few months later (Table IX).

Patient Mrs. A. DeR. (R-18) did not remember radium administration. Pain and

## TABLE IV †

### Radium Patients

| Pat. No. | Adm. (*Age-Year*) | Retained Radium Amt.-Time (μg) Meas. | Last Exam. | Symptoms (*Time*) | First Symptom | Second Symptom | Third Symptom |
|---|---|---|---|---|---|---|---|
| 1 | 60/1940 | .01/10 | 72/1952 | 0 | | | |
| 2 | 54/1936 | .02/14 | 68/1950 | 0 | | | |
| 3 | 33/1921 | .06/30 | 63/1951 | 0 | | | |
| 4 | 63/1930 | .4/21 | 83/1951 | ? | Marked arthritic changes. | | |
| 5 | 34/1912<br>39/1917 | .4/26 | 71/1950 | ? | Unusual dental caries. | | |
| 6 | 26/1902<br>56/1932<br>64/1940 | .4/31 & 48 | 73/1949 | ? | Unusual dental caries. 73/1949 | | |
| 7 | 23/1931 | .5/20 | 43/1951 | 0 | | | |
| 8 | 25/1934 | .5/16 | 42/1951 | 0 | | | |
| 9 | 27/1931 | .5/20 | 47/1951 | 0 | | | |
| 10 | 48/1921 | .5/23 | 71/1951 | 0 | | | |
| 11 | 50/1931 | .6/20 | 70/1951 | 0 | | | |
| 12 | 28/1931 | .6/20 | 48/1951 | 0 | | | |
| 13 * | 31/1931 | .7/20 | 51/1951 | 17/1948 | Pain in right hip and leg. | | |
| 14 | 28/1931 | .8/20 | 48/1951 | 0 | | | |
| 15 | 33/1931 | .8/20 | 53/1951 | 0 | | | |
| 16 | 23/1931 | .8/20 | 43/1951 | 0 | | | |
| 17 * | 36/1924 | .8/27 | 74/1952 | | Pain in back | Tumor of finger, 1950. | Cordotomy, 1952. |
| 18 * | 50/1927<br>62/1929 | .86/26 | 74/1951 | 20/1947 | Pain in leg. | Tumor of tibia. | Died in 1952 of tumor. |
| 19 | 22/1931 | .9/20 | 42/1951 | 0 | | | |
| 20 | 25/1931 | 1.0/20 | 45/1951 | 0 | | | |
| 21 | 18/1931 | 1.0/20 | 38/1951 | 0 | | | |
| 22 | 21/1931 | 1.0/20 | 51/1951 | 8?/1939 | 7 extractions. | | |
| 23 | 30/1926 | 1.1/25 | 56/1951 | 23/1949 | Stiffness, elbow. | | |
| 24 * | 25/1928<br>26/1949 | 1.3/25 | 48/1951 | 19/1947 | Pain in foot. | Generalized pain 1950. | Died in 1951, tumor of foot. |
| 25 | 17/1923 | 1.5/19 | 44/1950 | 27?/1947 | Injury—limitation, elbow. | | |
| 26 * | 53/1925 | 1.6/25 | 79/1951 | 14/1939 | Bone spicules—mandible. | 1941 Non-union, mandible. | |
| 27 * | 29/1925 | 1.6/26 | 55/1951 | 25/1950 | Pink tooth (dentist). | | |
| 28 | 22/1931 | 1.6/20 | 42/1951 | 9/1940 | Hip difficulty. | | |
| 29 | 20/1931 | 1.8/20 | 30/1951 | 0 | | | |
| 30 | 22/1931 | 1.9/20 | 52/1951 | 10/1941 | Pain, right hip. | | |
| 31 | 26/1931 | 2.6/20 | 56/1951 | ?/1951 | Aseptic necrosis, humerus 1951. | | |
| 32 | 22/1911 | 2.0/33 | 58/1946 | 0 | | | |
| 33 | 29/1931 | 2.6/20 | 49/1951 | 0 | | | |
| 34 | 28/1931 | 3.6/20 | 48/1950 | 19/1950 | Limp—left leg. | Tumor, right tibia. | |
| 35 | 33/1929<br>36/1932 | 4.2/22 | 65/1951 | 16/1945 | Pain in back. | Fracture, right femur, 1947. | |
| 36 | 47/1920 | 6/17 | 64/1937 | 9/1929 | Chronic arthritis. | Abscess of spine, 1929. | Swollen knee, 1936.<br>Died, tumor, 1937. |

† See page 186.

* Selected by symptoms.

## TABLE IV

### Radium Patients

| Skeletal X-ray (*Year*) | Skull | Mand. | Glen. P. | Hum. | Ra-dius | Ulna | Vert. | Pel-vis | Femur | Tibia | Fib. | Bones of Foot | Misc. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| X-1950 | | | | | | | | | | | | | |
| 1951 | | 0 | | | | | | 0 | | | | | |
| X-1951 | | | | | | | | | | | | | |
| X-1951 | | | | ± | ± | ± | | | ± | ± | | ± | |
| None | | | | | | | | | | | | | |
| 1944 | | 0 | | | | | | | | | | | |
| X-1951 | | | | X | | | | | | X | X | | |
| X-1951 | | | | | | | | | X | X | X | X | Hands |
| X-1951 | | | | | | | | | | | X | | |
| X-1951 | | | | | | | | | | | X | | |
| X-1951 | | | | | | | X | | | | | X | |
| X-1951 | | | | | | | | | | | | | |
| X-1951 | | | | | | | X | | X | | | | |
| X-1951 | | | | | | | | | | | | | |
| X-1951 | | | | | | | | | | | X | | |
| X-1951 | | | | | | | | | | | | | |
| 1950 | X | | | | | | | X | | | | | Finger |
| X-1952 | X | | | | | | X | | X | X | X | X | |
| X-1951 | | | | | X | X | | | | | | | |
| X-1951 | | | | X | X | | | | | | X | | |
| X-1951 | | | X | | | | | | | | X | | |
| X-1951 | | | | | X | X | | | | X | X | | |
| X-1951 | | X | X | | X | X | X | | X | X | X | | |
| X-1950 | X | X | X | X | X | X | X | X | X | X | X | X | |
| 1950 | X | | | | | | | | | | X | | |
| X-1951 | X | X | | | X | X | | | | X | X | | Hand |
| X-1951 | X | X | X | X | X | X | X | X | | X | X | | |
| X-1951 | | | | X | | | | X | X | X | X | | |
| X-1951 | | | | | X | | | | | X | X | | |
| X-1951 | | | | X | X | X | X | X | X | X | X | X | |
| X-1951 | | | X | X | | | | | X | | | | |
| 1947 | | | | X | | | | | | | X | | |
| None | | | | | | | | | | | | | |
| X-1951 | X | X | | X | X | | X | X | X | X | X | X | |
| X-1951 | X | | X | X | X | X | X | X | X | X | X | X | |
| 1932 | X | X | | | | | | | X | | | X | Ribs |

X with date signifies complete skeletal survey. ± Signifies minimal or questionable changes.

Table IV *(continued)*

| Pat. No. | Adm. (*Age-Year*) | Retained Radium Amt.-Time (µg) Meas. | Last Exam. | Symptoms (*Time*) | First Symptom | Second Symptom | Third Symptom |
|---|---|---|---|---|---|---|---|
| 37 | 55/1952 | 5.5/14 | 83/1950 | 21/1943 | Lost two teeth. | Draining sinuses, mandible, 1949. | |
| 38 | 51/1922<br>58/1929 | 5.4/29 | 80/1951 | 0 | | | |
| 39 | 25/1926 | 5.6/25 | 52/1951 | 22/1948 | Bone spicules—jaw. | | |
| 40 | 25/1931 | 6.7/20 | 48/1951 | 0? | | | |
| 41 | 44/1926 | 7/22 | 66/1948 | 14/1940 | Osteomyelitis—jaw. | | |
| 42 | 48/1918 | 10.5/23 | 80/1950 | 25/1933 | Fracture—foot. | Anaemia. | Died in 1954, anaemia. |
| 43 * | 41/1922 | 10?/25 | 66/1947 | 22/1944 | Arthritis of hip and knees. | Bedridden, 1947. | Died in 1947, multiple causes. |
| 44 | 52/1927<br>54/1929 | 10.7/24 | 76/1951 | 2/1931 | Pain in hips, 1949 | | |
| 45 | 40/1926 | 9/22 | 63/1949 | 21/1948 | Pain in left arm | Tumor, left arm<br>Aplastic anaemia, 1948. | Died from tumor, 1949. |
| 46 * | 42/1928 | 11.5/21 | 74/1950 | 17/1945 | Fracture—spine | Osteomyelitis, jaw, 1949. | |
| 47 * | 37/1922<br>42/1927 | 11.3/25–30 | 75/1950 | 15?/1935 | Pain in hips. | Lost mandible, 1942. | |
| 48 | 36/1925<br>1930 | 11.5/15 | 61/1950 | 11/1936 | Fracture—spine. | Osteomyelitis, jaw, 1938. | |
| 49 | 43/1926 | 13.9/25 | 68/1951 | 14/1940 | Arthritis—feet | | |
| 50 * | 42/1922<br>44/1924 | 23/10 | 69/1949 | 7/1931 | Osteomyelitis—mandible. | | |

Summary of the clinical findings and roentgenographic changes of the patients who were given radium medically (Boston and Chicago series). For example, patient 30, column 1, was given radium in 1931 (age twenty-two years). Twenty years later, 1.9 micrograms of radium were estimated to be in her body. Last physical examination was in 1951 when she was fifty-two years old. In 1941, ten years after she had received radium, pain in the hip began. In 1951, complete skeletal roentgenographic examination was done and the humerus, radius, ulna, vertebrae, pelvis, femoral head, tibia, fibula, and bones of the feet showed changes characteristic of the deposition of radioactive elements.

swelling began following a slight injury to the tibia in 1947 (Fig. 6-A). A roentgenographic diagnosis of osteomyelitis was made and the patient was given a course of ten x-ray treatments [6]. The improvement following x-ray therapy was considered to be highly suggestive of Ewing's tumor. Later in 1947, a histological diagnosis of osteoid osteoma was made from the biopsied bone [9] In 1948, the possibility of a giant-cell tumor was considered, and the lesion was curetted (Fig. 6-B). In 1949, a high amputation was performed following a pathological fracture of the femur [8] (Fig. 7). On physical examination in February 1952, the patient was found to be emaciated and weak, having had considerable weight loss. There had been pain in the middle of the back, to the right of the mid-line, for one month. A chest roentgenogram revealed multiple metastases throughout the lung fields and erosion of the ninth right rib (Fig. 8) [24]. The patient died a short time later from what was considered to be generalized metastases from an osteogenic sarcoma. Osteogenic sarcoma was found in the histological sections taken in 1949 (Figs. 9 and 10)[13] (Table IX).

The history of this patient illustrates two points with regard to the deposition of radioactive elements. The first point is that this patient did not remember having received radium. The second point is that the establishment of a diagnosis caused considerable confusion because the skeletal changes resulting from the deposition of radioactive elements were not recognized. The diagnoses of osteoid osteoma, osteomyelitis, Ewing's tumor, TABLE IV *(continued)*

| Skeletal X-ray (*Year*) | Skull | Mand. | Glen. P. | Hum. | Radius | Ulna | Vert. | Pelvis | Femur | Tibia | Fib. | Bones of Foot | Misc. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1940 | | X | | | | | | | X | | | | |
| X-1951 | X | | | X | X | X | X | X | X | X | X | X | |
| X-1951 | X | X | | X | X | X | X | X | X | X | X | | |
| X-1951 | | | X | X | X | X | X | X | X | X | X | X | |
| 1948 | | X | | X | X | X | | | X | X | X | X | |
| 1941 | | X | | X | | | | X | X | X | X | X | |
| 1947 | | | X | | | | X | X | X | X | X | X | Patella |
| X-1951 | X | X | X | X | X | X | X | X | X | X | X | X | |
| | | | | | | | | | | | | X | |
| 1948 | | | | | X | | | | | X | X | | Changes in many long bones |
| 1945 | | X | | | | | X | | | | | | |
| 1947 | | X | X | | | | | | X | X | X | | |
| 1936 | | X | | | | | | X | | | | | |
| X-1951 | | X | | | X | X | X | | | | X | X | |
| X-1946 | X | X | X | X | X | X | X | X | X | X | X | X | Ribs, clavicles, hands |

giant-cell tumor, and multiple myeloma were entertained in the two-year period, 1947 to 1949.

Patient M. K. (R-24) had noted the onset of pain in the left foot eighteen years (1948) after the administration of radium water [7]. Roentgenograms of the foot a few months later revealed an area of decreased density in the left tarsal navicular (Fig. 11) [12]. The condition became so severe that it necessitated the use of a cane. Roentgenograms at that time revealed marked destructive changes of the tarsal bones (Fig. 12). Because of the marked increase in symptoms and the destructive changes in the foot in 1950, a biopsy was done and fibrosarcoma was diagnosed on histological examination of the specimen (Fig. 13) [5]. The pain became generalized and required more and more analgesics to control; it was described as boring and burning in character. Intermittently, sharp knife-like pains occurred which lasted for a few seconds. The pain was not significantly influenced by motion, position, and temperature. The leg was amputated below the knee in February 1951. Examination of the amputated tibia revealed extension of the tumor. A sarcomatous lesion developed on the end of the stump a few weeks after the operation. The patient died in August 1951, as a result of generalized metastases. Areas of fibrosarcoma were found throughout the skeleton (Fig. 14). In some parts of cancellous bone, it was difficult to distinguish between the fibrosarcoma and the fibrous connective tissue found in the trabecular spaces of patients without malignant involvement (Fig. 15) (Table IX) [10].

It is evident from the case histories of patients I. D. (L-21) and Mrs. A. DeR. (R-18) that the transition from a benign to a malignant lesion may be similar to that in many skeletal diseases. Both of these patients were first considered to have osteomyelitis and then osteoid osteoma. In patient M. B. (R-17) the diagnosis of osteoid osteoma of the

TABLE V

LUMINOUS-DIAL WORKERS

| Pat. No. | Employ. (*Age-Year*) | Retained Radium Amt.-Time (μg) to Meas. | Last Exam. (*Age-Year*) | Symptoms (*Time from Employ.*) | First Symptom | Second Symptom | Third Symptom |
|---|---|---|---|---|---|---|---|
| 1 | 19/1924 | .02/28 | 47/1952 | 0 | Hypertrophic arthritis | | |
| 2 | 14/1941<br>17/1943 | .06/11 | 25/1952 | | | | |
| 3 | 18/1922<br>19/1923 | .1/30 | 47/1952 | 29/1951? | Pain in long bones | | |
| 4 | 12/1921<br>14/1923 | .2/31 | 43/1935 | 14/1935 | All teeth removed | | |
| 5 | 20/1924<br>47/1952 | .25/28 | 47/1952 | 0 | | | |
| 6 | 22/1933<br>41/1952 | .34/18 | 41/1952 | 0 | | | |
| 7 | 31/1925<br>33/1927 | .4/27 | 58/1952 | 0 | | | |
| 8 * | 16/1922<br>17/1923 | .5/30 | 46/1952 | 11/1934 | Pain in arm—sarcoma<br>Arm removed | Pain, left ankle (1949) | Pain, right ankle (1952) |
| 9 * | 20/1926<br>22/1928 | .7/26 | 44/1950 | 5/1931 | Lost all teeth | Pain in shoulder (1941) | |
| 10 | 16/1923<br>22/1929 | .7/27 | 44/1951 | 0 | | | |
| 11 | 17/1923<br>45/1952 | .79/29 | 29/1949 | 29/1949 | Teeth removed<br>Abscesses | | |
| 12 * | 18/1919<br>20/1921 | .9/24 | 45/1950 | 1/1920 | Dental decay | Running ears and sloughing ossicles (1935) | Spontaneous fractures (1941, 1944, 1948, 1950) |
| 13 | 28/1923<br>30/1927 | 1.2/29 | 55/1952 | 14/1937 | Bone spicules<br>All teeth removed | | |
| 14 * | 21/1927<br>45/1951 | 1.3/24 | 45/1951 | 21/1948 | Fracture, femur | Refracture, femur (1948) | Tumor of ischium (1953) |
| 15 * | 17/1917<br>19/1919 | 1.0/32 | 49/1949 | 25/1942 | Lost teeth, radiation osteitis, mandible | Mass—mandible<br>Carcinoma—1948 | |
| 16 * | 18/1921 | 1.5/15 | 33/1936 | 12/1933 | Fracture, mandible | Died—Giant-cell tumor of mandible, 1936 | |
| 17 | 29/1916<br>32/1919 | 1.5/32 | 61/1948 | 4/1920 | Fracture, femur, 1948 | | |
| 18 | 43/1926 | 2/24 | 67/1950 | 0 | | | |
| 19 * | 28/1921<br>32/1925 | 2.5/12 | 55/1948 | 8/1929 | Osteomyelitis—jaw | Fracture foot (1937 and 1948) | |
| 20 * | 16/1916<br>19/1919 | 2.9/32 | 48/1949 | 27/1943 | Teeth and mandible | Pain in neck (1949) | Died of carcinoma, left temporal bone (1949) |
| 21 * | 15/1923 | 3.8/29 | 45/1952 | 9/1932 | Knife-like pain in left hip | Pain in right hip, femoral head removed 1945 | Unable to walk (1947)<br>Died, tumor of femur (1953) |

* Selected by symptoms.

X with date signifies complete skeletal survey.

Time from employment as a luminous-dial worker was based on the date at which the patient began work.

TABLE V

LUMINOUS-DIAL WORKERS

| Skeletal X-ray (*Year*) | Skull | Mand. | Glen. | Hum. | Radius | Ulna | Vert. | Pelvis | Femur | Tibia | Fib. | Bones of Feet | Misc. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| X-1952 | | | | | | | | | | | | | |
| X-1952 | | | | | | | | | | | | | |
| X-1952 | | | | | | | | | | | | | |
| X-1952 | | | | | | | | | | | | | |
| None | | | | | | | | | | | | | |
| None | | | | | | | | | | | | | |
| X-1952 | | | | | | | | | | | | | |
| X-1952 | X | | | X | | | | | X | X | X | X | |
| 1940 and 1945 | X | X | X | X | | | | X | X | | | X | |
| X-1951 | | | | | | | | | | | X | X | |
| None | | | | | | | | | | | | | |
| 1950 | | | Extreme degree of radiation damage throughout the skeleton. | | | | | | | | | | |
| X-1952 | | | | X | X | X | | | | | X | | |
| X-1951 | X | | | | X | X | | X | X | X | X | X | |
| 1950 | X | X | | | | | | | | | | | |
| 1935 | | X | | | | | | | | | | | |
| 1948 | | | Scattered areas of radiation damage throughout skeleton. | | | | | | | | | | |
| 1950 | X | | | X | | | | | | | | | |
| 1940 | | X | | | X | | | | X | | | X | |
| 1948 | X | X | | | X | | | X | | X | X | | |
| X-1952 | X | X | X | X | X | X | X | X | X | X | X | X | |

TABLE V *(continued)*

| Pat. No. | Employ. *(Age-Year)* | Retained Radium Amt.-Time (μg) to Meas. | Last Exam. *(Age-Year)* | Symptoms *(Time from Employ.)* | First Symptom | Second Symptom | Third Symptom |
|---|---|---|---|---|---|---|---|
| 22 * | 20/1923<br>23/1926 | 4.0/25 | 45/1948 | 9/1932 | Pain and stiffness hip and shoulder joints | Teeth removed 1935 | Severe arthritis (1948) |
| 23 * | 21/1918<br>22/1919 | 6.5/22 | 48/1945 | 17/1938 | Vague bone pains | Pain over tibia (1944) | Died, sarcoma tibia (1945) |
| 24 * | 16/1917<br>17/1918 | 8.0/33 | 49/1950 | 11/1928 | Considerable dental difficulties | Vague bone pain<br>Beginning deafness, 1944 | Fracture of right femur (1945) |
| 25 * | 19/1919 | 10/19 | 38/1939 | 17/1936 | Pain in hips—limp | Left facial neuralgia (1937) | Died of carcinoma, ethmoid sinuses (1938) |
| 26 * | 50/1927 | 10/12 | 62/1939 | 12/1939 | Pain and swelling of mandible | Died of bronchopneumonia after operation on mandible 1939 | |
| 27 * | 19/1921<br>25/1927 | 10/31 | 48/1952 | 16/1937 | Fracture of left femur | Fracture of right femur, 1938<br>Refracture, left femur, 1945<br>Paralytic bladder. Died 1951 | |
| 28 * | 16/1922 | 18/14 | | 9/1931 | Pain in right ankle | Osteomyelitis of maxilla and mandible—1932 | Supposedly died from leukaemia and renal insufficiency (1938) |

finger had been made one year prior to the diagnosis of osteogenic sarcoma. Characteristic histopathological changes due to the disposition of radioactive elements were found in reviewing the specimens from which these diagnoses were made.

The history of patient C. P. (L-8) emphasizes the need to follow these patients carefully. Patient C. P. has led a relatively normal life since 1934 as a result of prompt attention to symptoms occurring in the elbow. Following a biopsy and histological diagnosis of osteogenic sarcoma, the arm was disarticulated at the shoulder.

Figure 19 shows the sites of origin of the tumors that developed in thirteen of the seventy-eight patients. Eight of these patients were luminous-dial workers and five were given radium for medical purposes. Table X gives the age at the time of administration, the time from administration until the first symptoms occurred which could reasonably be attributed to the deposition of radioactive elements, the time from the first symptom until death, and the amount of retained radium. Since both groups of patients have approximately the same amount of radium retained in the body for about the same length of time it is not possible to make any differentiation between luminous-dial workers and patients who were given radium in relation to the estimated radium present. The average age at the time of employment in the luminous-dial workers was seventeen years as contrasted with thirty-nine years as the average age at the time of the administration of radium.

Most of the patients in whom malignant tumors eventually develop follow a similar course. There is a latent period followed by symptoms which usually develop from changes in weight-bearing bones and bones which are subject to repeated trauma. Later tumor

TABLE V *(continued)*

| Skeletal X-ray *(Year)* | Skull | Mand. | Glen. | Hum. | Radius | Ulna | Vert. | Pelvis | Femur | Tibia | Fib. | Bones of Feet | Misc. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1948 | X | X | | | X | | | | X | | X | | |
| | | | | | | | | | X | | | | |
| 1950 | X | X | X | | | | X | X | | | | | |
| 1936 | X | X | | | | | | | X | X | X | | |
| 1949 | X | X | | | | | | | | | | | |
| 1952 | X | | X | X | X | X | | | X | | | | |
| 1936 | | | | X | | | X | X | X | | | X | |

formation occurs at a site which is usually not the site of the initial symptoms. When the malignant tumor develops, there may be a marked accentuation of the disease process, and death usually occurs about one to four years after the symptoms at the site where the tumor originated.

## SYMPTOMS

Martland first described the clinical course of patients following the internal deposition of radioactive materials [19]. The clinical course of a few of these patients who had ingested exceedingly large amounts of radioactive materials was similar in certain respects to the acute radiation syndrome from external irradiation found in the Japanese atomic-bomb casualties [14], and in the patients reported by Hempelmann, Lisco, and Hoffman who were exposed to external irradiation from various sources. The patients became weak, and there was usually an infection in the mouth and pharynx with an associated anaemia. Fever developed and gradually increased. The lesions in the mouth and throat increased in severity with eventual necrosis, sloughing, and bleeding. Large purpuric areas appeared over the body as the pancytopenia became more severe. The patient usually became prostrated and often delirious. Death seemed to occur as a result of the infection, the pancytopenia, and circulatory collapse. Autopsy findings in these patients were also similar to those found following the acute radiation syndrome [14,20].

Other patients, for example, the technical director of a luminous-dial factory, died

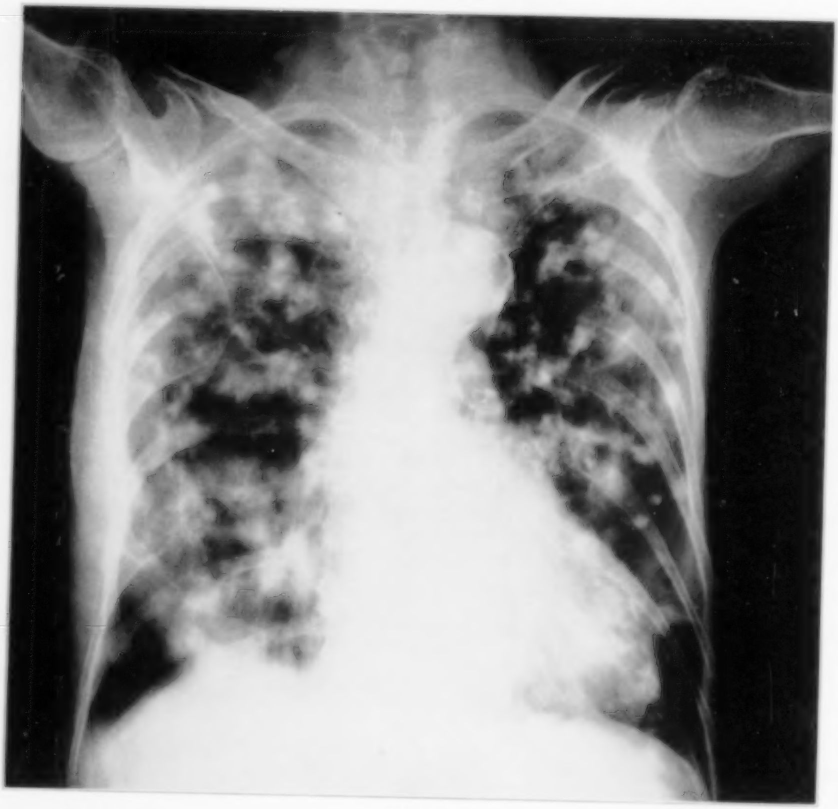


FIG. 8

Roentgenogram of the chest of Mrs. A. DeR. (R-18) made on routine examination in 1951. Note the multiple areas of increased density throughout the lung fields and the erosion of the ninth rib on the right. (Courtesy, Dr. E. H. Fell and Dr. Faye Squire, Presbyterian Hospital, Chicago, Illinois.)

from aplastic anaemia. Martland stated that the clinical course of such patients was similar to that seen in chronic benzene poisoning or in the acute leukaemias. Before the relationship between the ingestion of the radioactive materials and the development of malignant disease was understood, some of the causes of death in the luminous-dial workers were listed as follows: ulcerative stomatitis, syphilis, primary anaemia, Vincent's angina, phosphorus poisoning, and necrosis of the jaw.

The clinical manifestations seen as a result of large amounts of internally deposited radioactive materials and external irradiation are not present in those people who have smaller amounts of radioactive materials and in whom symptoms develop many years after the skeletal deposition of the radioactive elements. Death may occur from anaemia, crippling bone lesions, or tumor formation, or all three, while some patients may never have any symptoms from the effects of the internally deposited radioactive elements.

Symptoms which can be reasonably attributed to radioactive element deposition usually result from destructive changes in the skeleton (Table XI). When symptoms do occur as a result of skeletal change, they are usually not severe in comparison with the extent of skeletal damage. In some instances, there is neither a progression of the skeletal lesions nor of the symptoms following the production of the skeletal change. For example, aseptic necrosis of the head of the femur in patient R. D. (R-30) developed in 1940 (age thirty years). This was followed by limping and discomfort on walking. However, during

## TABLE VI

### Radium Patients †

| Pat. No. | Adm. Age-Year | Retained Radium Amt.-Time (μg) to Meas. | Skeletal X-Ray (*Year*) | Skull | Mand. | Glen. | Hum. | Radius | Ulna | Vert. | Pelvis | Femur | Tibia | Fib. | Bones of Feet | Misc. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 60/1949 | .01/10 | 1950 | | | | | | | | | | | | | |
| 3 | 33/1921 | .06/30 | 1951 | | | | | | | | | | | | | |
| 4 | 63/1930 | .4/21 | 1951 | | | | | | | | | | | | | |
| 7 | 23/1931 | .5/20 | 1951 | | | | X | | | | | | X | X | | |
| 8 | 25/1934 | .5/16 | 1951 | | | | | | | | | X | X | X | X | Hands |
| 9 | 27/1931 | .5/20 | 1951 | | | | | | | | | | | X | | |
| 10 | 48/1921 | .5/23 | 1951 | | | | | | | | | | | X | | |
| 11 | 50/1931 | .6/20 | 1951 | | | | | | | X | | | | | X | |
| 12 | 28/1931 | .6/20 | 1951 | | | | | | | | | | | | | |
| 13 | 31/1931 | .7/20 | 1951 | | | | | | | X | | X | | | | |
| 14 | 28/1931 | .8/20 | 1951 | | | | | | | | | | | | | |
| 15 | 33/1931 | .8/20 | 1951 | | | | | | | | | | | X | | |
| 16 | 23/1931 | .8/20 | 1951 | | | | | | | | | | | | | |
| 18 | 60/1927 | .87/26 | 1952 | X | | | | | | X | | X | X | X | | |
| 19 | 22/1931 | .9/20 | 1951 | | | | | X | X | | | | | | | |
| 20 | 25/1931 | 1.0/20 | 1951 | | | | X | X | | | | | | X | | |
| 21 | 18/1931 | 1.0/20 | 1951 | | | X | | | | | | | | X | | |
| 22 | 21/1931 | 1.0/20 | 1951 | | | | | X | X | | | | X | X | | |
| 23 | 30/1926 | 1.1/25 | 1951 | | X | X | | X | X | X | | X | X | X | | |
| 24 | 25/1928 | 1.3/23 | 1950 | X | X | X | X | X | X | X | X | X | X | X | X | |
| 26 | 53/1925 | 1.6/25 | 1951 | X | X | | | X | X | | | | X | X | | Hands |
| 27 | 29/1925 | 1.6/26 | 1951 | X | X | X | X | X | X | X | X | | X | X | | |
| 28 | 22/1931 | 1.6/20 | 1951 | | | | X | | | | X | X | X | X | | |
| 29 | 20/1931 | 1.8/20 | 1951 | | | | | X | | | | | X | X | | |
| 30 | 22/1931 | 1.9/20 | 1951 | | | | X | X | X | X | X | X | X | X | X | |
| 31 | 26/1931 | 2.6/20 | 1951 | | | X | X | | | | | X | | | | |
| 34 | 28/1931 | 3.6/20 | 1951 | X | X | | X | X | | X | X | X | X | X | X | |
| 35 | 33/1929 | 4.2/22 | 1951 | X | | X | X | X | X | X | X | X | X | X | X | |
| 38 | 51/1922 | 5.4/29 | 1951 | X | | | X | X | X | X | X | X | X | X | X | |
| 39 | 25/1926 | 5.6/25 | 1951 | X | X | | X | X | X | X | X | X | X | X | | |
| 40 | 25/1931 | 6.7/20 | 1951 | | | X | X | X | X | X | X | X | X | X | X | |
| 44 | 52/1927 | 10.7/24 | 1951 | X | X | X | X | X | X | X | X | X | X | X | X | |
| 49 | 43/1926 | 13.9/25 | 1951 | | X | | | X | X | X | | | | X | X | |
| 50 | 42/1922 | 22/10 | 1934 | X | X | X | X | X | X | X | X | X | X | X | X | Ribs, clavicles, hands |

† Only patients who had complete roentgenographic examination.

TABLE VII

LUMINOUS-DIAL WORKERS †

| Pat. No. | Adm. Age-Year (μg) to Meas. | Retained Radium Amt.-Time (*Year*) | Skeletal X-ray | Skull | Man-dible | Gle-noid |
|---|---|---|---|---|---|---|
| 1 | 19/1924 | .02/28 | 1952 | | | |
| 2 | 14/1941 | .06/11 | 1952 | | | |
| 3 | 18/1922 | .1/30 | 1952 | | | |
| 4 | 12/1921 | .2/31 | 1952 | | | |
| 7 | 31/1925 | .4/27 | 1952 | | | |
| 8 | 16/1922 | .5/30 | 1952 | X | | |
| 10 | 16/1923 | .7/27 | 1951 | | | |
| 13 | 28/1923 | 1.2/29 | 1952 | | | |
| 14 | 21/1927 | 1.3/24 | 1950 | X | | |
| 21 | 15/1923 | 3.8/29 | 1952 | X | X | X |

† Only patients who had complete roentgenographic examinations.

the period between the onset of symptoms and the examination in 1951, little progression of either limping or discomfort on walking occurred. There was also minimal discomfort following the aseptic necrosis of the head of the radius in patient G. L. (R-23) since the beginning of symptoms in 1947. Patient C. S. (R-28) was a mental patient who could not be interrogated. Nevertheless, the patient experienced little discomfort on walking when examined in 1951. Changes seen in roentgenograms of the pelvis in 1940 (age thirty-two years) were interpreted as an old osteochondritis of the heads of the femora; in 1951 bilateral aseptic necrosis of the femoral head was present. Patient H. V. (R-13) had aseptic necrosis of the head of the femur twenty-two years after the administration of radium at the age of fifty years [21,23]. She had no other symptoms or changes that could be related to the deposition of radioactive elements.

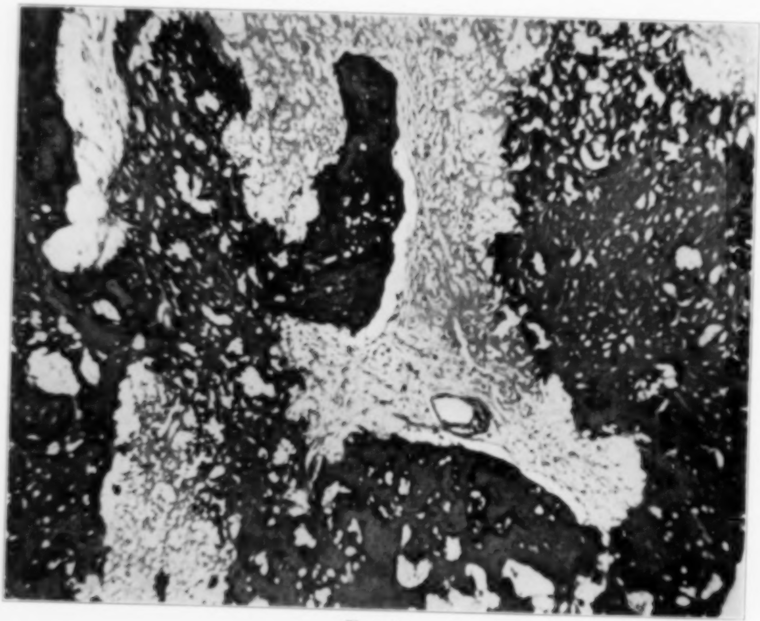


FIG. 9

Photomicrograph of a histological section from the tibia of Mrs. A. DeR. (R-18) made in 1947. Note the bone destruction and replacement with fibrous connective tissue. (Courtesy Dr. G. M. Hass, Presbyterian Hospital, Chicago, Illinois.)

TABLE VII

LUMINOUS-DIAL WORKERS

| Humerus | Radius | Ulna | Vert. | Pelvis | Femur | Tibia | Fibula | Bones of Feet | Misc. |
|---|---|---|---|---|---|---|---|---|---|
| X | | | | | X | X | X | X | |
| | | | | | | | X | X | |
| X | X | X | | | | | X | | |
| | X | X | | X | X | X | X | X | |
| X | X | X | X | X | X | X | X | X | |

Skeletal changes usually occur in bones subject to weight-bearing or to repeated trauma [18]. Aseptic necrosis usually occurs in the heads of the femora and the bones of the feet. Collapse of the vertebrae is occasionally found, while fractures almost always occur in the femoral shaft. Patient M. L. (L-27) fractured her left femur while pressing her foot to the floor of an automobile. Patients R. W. (L-14) and J. J. (R-35) sustained fractures of the shafts of the femur on minimal trauma. Healing of the fractures was delayed, but proper union occurred in all patients. Rarely, patients may have femoral fractures with permanent non-union. Patient J. J. had collapse of some of the vertebral bodies with associated pain that required the wearing of a Taylor brace for control, while patient A. DeR. (R-44) had more marked vertebral changes with minimal discomfort.

TABLE VIII

SUMMARIES OF CASE HISTORIES OF THE PATIENTS IN THE CHICAGO AND BOSTON STUDIES IN WHOM MALIGNANT TUMORS DEVELOPED *

| Total Body Radium (*Micrograms*) | Patient's Initials | Patient's Number ** |
|---|---|---|
| .5 | C. P.* | L-8 |
| .8 | M. B. | R-17 |
| .8 | Mrs. A. DeR.* | R-18 |
| 1.0 | F. C. | L-15 |
| 1.3 | M. K.* | R-24 |
| 1.3 | R. W.* | L-14 |
| 1.5 | K. M. | L-16 |
| 2.9 | H. G. | L-20 |
| 3.8 | I. D.* | L-21 |
| 6.0 | C. I. | R-36 |
| 6.5 | F. R. | L-23 |
| 9.0 | F. W. | R-45 |
| 10.0 | M. L. | L-25 |

Key:
(L)—Luminous Dial Workers
(R)—Radium Patients

---

* These patients' histories are given in Table IX.

** The patients are designated by the numbers found in Tables IV and V. Luminous-dial workers have the letter L preceding the number and the patients who received radium have the letter R preceding the number. In patient 103 of the Chicago report a fibrosarcoma of the first sacral vertebra has developed (not included in this report). An osteogenic sarcoma developed in the tibia of patient C. L. (R-34).

TABLE IX

Representative Case Histories

| Total Body Radium (*Micrograms*) | Patient's Initials | Patient's Number |
|---|---|---|
| 0.5 | C. P.* | L-8 |
| 0.7 | H. V. | R-13 |
| 0.8 | Mrs. A. DeR.* | R-18 |
| 1.1 | G. L. | R-23 |
| 1.3 | M. K.* | R-24 |
| 1.3 | R. W.* | L-14 |
| 1.6 | W. B. | R-26 |
| 1.6 | C. S. | R-28 |
| 1.9 | R. D. | R-30 |
| 2.5 to 10 | K. B. | R-43 |
| 3.6 | C. L.* | R-34 |
| 3.8 | I. D.* | L-21 |
| 4.2 | J. J. | R-35 |
| 6.0 | M. L. | L-27 |
| 10.7 | A. DeR. | R-44 |
| 11.3 | M. H. | R-47 |
| 13.9 | J. F. | R-49 |

* Patients in whom malignant tumors developed. Since the preparation of this report, an osteogenic sarcoma has developed in the right tibia of patient R-34.

Many of the patients did not have any symptoms which might be attributed to radium intake. Other than an increased risk of skeletal injury or tumor formation, they may never have any recognized clinical changes as a result of radioactive element deposition.

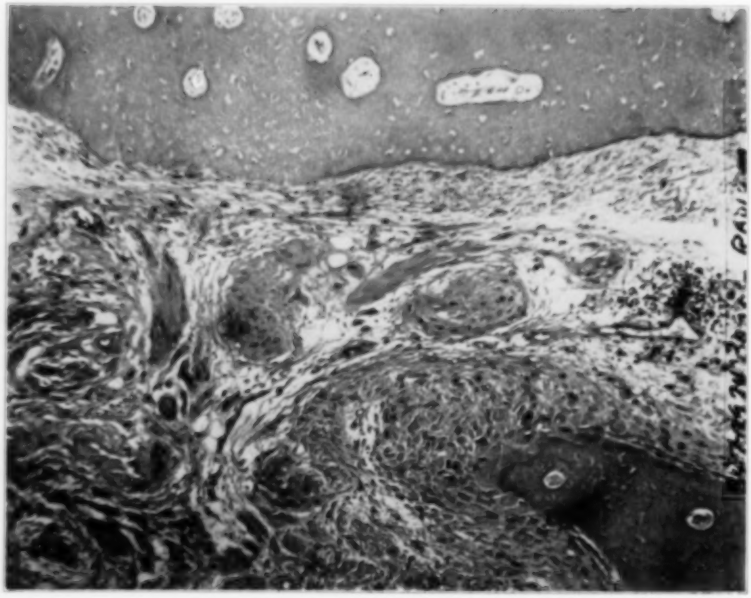


Fig. 10

Photomicrograph of histological section of one of the areas that is beginning to undergo malignant change. Patient I. D. (L-21).

TABLE X

Time Interval Between Deposition of Radio-Elements and Occurrence of Symptoms, Tumor Formation, and Death in the 1931 and 1951 Investigations

| | No. of Patients | Average Age at Adm. (*Years*) | Average Time to 1st Symptom from Adm. (*Years*) | Average Time from 1st Symptom to Death (*Years*) | Average Retained Radium (*Micrograms*) |
|---|---|---|---|---|---|
| Luminous-Dial Patients (1931 Series) | 5 | 17 | 8 | 2 | 23<br>(6-50) |
| Range—Years | | 16–21 | 4–11 | 1/6–4 | |
| Luminous-Dial Patients (1951 Series) | 8 | 17 | 19 | 7 | 3.4<br>(.5–10) |
| Range—Years | | 15–21 | 10–27 | 1–22 | |
| Radium Patients (1951 Series) | 5 | 39 | 21 | 5 | 3.1<br>(.8–8) |
| Range—Years | | 25–49 | 9-25 | 1–8 | |

In reviewing the histories and serial roentgenograms of these patients, it appears that periods may occur in which there is a considerable progression of symptoms followed by periods of quiescence. In patient I. D. (L-21) symptoms began during pregnancy and subsided following the delivery of the child.

These patients may die as a result of secondary infection. Patient M. L. became debilitated after multiple injuries as a result of internally deposited radioactive materials. A urinary tract infection occurred, and a paralytic bladder and moderate anaemia eventually developed. Various therapeutic measures failed to alter her downhill course.

Death may be the result of anaemia, as in the case of A. DeR. (R-44). There was a gradual and continual deterioration of the patient's general health, with anorexia, weight loss, weakness, emaciation, and gradually increasing pain in various parts of the body. Intermittent ear infections were present with a loss of hearing. Anaemia developed which gradually became worse, and the patient died.

In attempts to correlate clinical change with the amount of radium in the body, marked variations were found. The history of patient J. F. (R-49) illustrates this clinical observation. The only difficulty that he had was a march fracture of the foot which had healed uneventfully. The patient was asymptomatic at the time of examination in 1951 and only minor skeletal roentgenographic changes were present which could reasonably be attributed to the deposition of radioactive elements. Fourteen micrograms were present in his body, fifteen to thirty times the amount present in some patients who had severe skeletal changes or tumor formation.

Three patients had relief of symptoms and increased motion of the limbs following the administration of ACTH and cortisone. Patient M. L. (L-27) lost the use of her right arm. It was necessary to carry the arm in a sling and intense pain occurred at times which required increasing amounts of analgesics to control. Following the administration of cortisone for three months, there was some relief of pain in the elbow and some reduction of stiffness. The cortisone had no effect on the hand and wrist. In February 1952, patient A. DeR. (R-44) was given cortisone for three weeks, and a marked improvement in pain and range of motion of the right leg occurred after one week of therapy. Patient I. D. (L-21) was given ACTH for three weeks. After one week the patient was able to raise both legs off the bed; this she had been unable to do for years. The improvement subsided immediately after ACTH was stopped.

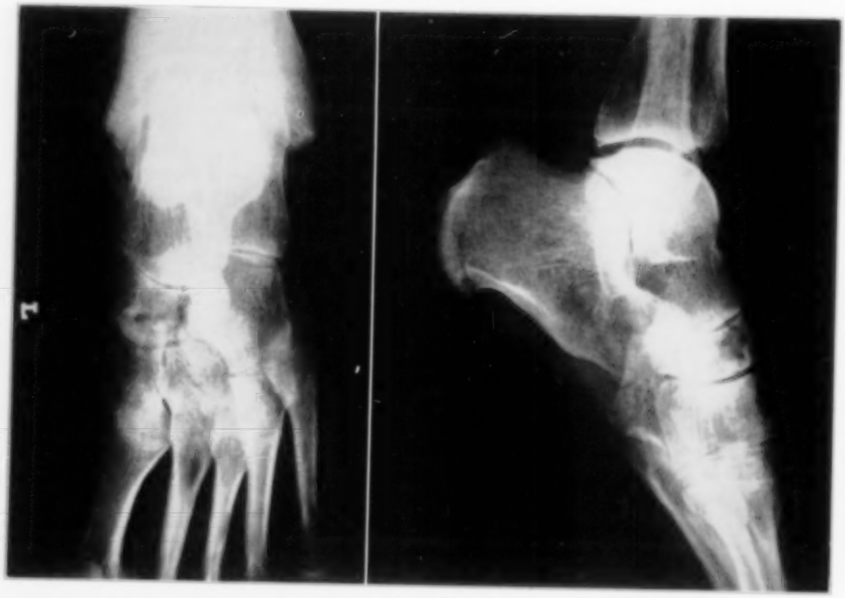


FIG. 11

Roentgenograms of the left foot of patient M. K. (R-24) made in 1948. Note the area of decreased density in the tarsal navicular. (Courtesy, Dr. Joseph Davis, St. Luke's Hospital, and Dr. Robert Potter, Northwestern University, Chicago, Illinois.)

Lesions of the maxilla and mandible are still one of the most frequent clinical findings; however, they are much less severe than in the earlier cases. Some of the patients may have only intermittent infections with extrusion of small bone spicules from the mandible. Nevertheless, in a few instances the infections and destructive process may continue until non-union or partial loss of the mandible occurs. [See Cases, W. B. (R-26), A. DeR. (R-44), and M. H. (R-47).]

Changes in the teeth may occur which can lead to the diagnosis of radioactive element deposition. Destructive changes in the teeth cause a reduction in the density which gives a pinkish hue to the teeth. The question of previous radioactive element administration should be considered when these dental changes are found or when a history of small bony spicules coming from the mandible is elicited in the older age group.

The results of these studies indicate that the route of intake is probably not as important as it was previously thought to be. Patients given radium by intravenous administration have the same difficulty with the teeth, maxillae, and mandible as the luminous-dial workers and those people given radium orally. The severity of the oral lesions in the early cases was probably in part the result of changes associated with the acute radiation syndrome. It appears that the combination of these two factors led to an overemphasis on the oral lesions from internal deposition of radioactive elements. It seems more likely that frequency of the changes in the mandible are the result of repeated pressure on the maxillae and mandible when the teeth are brought in apposition in closing the mouth, of radioactive element deposition in the mandible and maxillae, and the bacterial flora of the mouth.

## LABORATORY DATA

The hematological findings from thirty-six patients of the Chicago series are given in Table XII. The elevation of the erythrocyte-sedimentation rate was the most consistent hematological finding in these patients. The erythrocyte-sedimentation rate in thirty-four

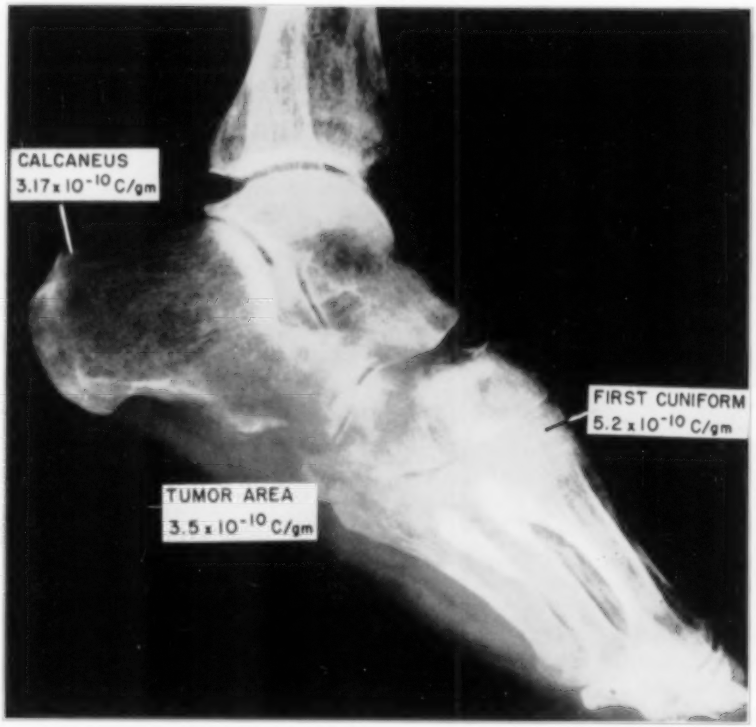

CALCANEUS
$3.17 \times 10^{-10}$ C/gm
FIRST CUNIFORM
$5.2 \times 10^{-10}$ C/gm
TUMOR AREA
$3.5 \times 10^{-10}$ C/gm

FIG. 12

Roentgenogram of the left foot of patient M. K. (R-24) made in 1951. Note the marked destruction of the tarsal bones of the foot. The tarsal navicular is completely destroyed. There was little difference in the radium concentration of the specimens taken for radiochemical analysis. (Courtesy, Dr. Joseph Davis, St. Luke's Hospital, and Dr. Robert Potter, Northwestern University, Chicago, Illinois.)

of the thirty-nine patients was elevated above twenty millimeters in one hour. Changes in the erythrocytes occurred more frequently in patients having greater amounts of retained radium. There was usually a slight anisocytosis, poikilocytosis, and mild hypochromia. However, the erythrocytes of some of the patients who had the greatest amount of radium were normal. There was some suggestion that minor reductions in the hemoglobin and erythrocyte values with an increase in the leukocyte count and lymphocyte values were beginning to occur. The changes in lymphocyte values were the most definite, but none of these changes were statistically significant.

Table XIII gives the serum calcium, serum phosphorus, and alkaline phosphatase values in twenty-four patients of the Chicago series having between .07 and 11.4 micrograms of retained radium [15]. There was some elevation of the serum phosphorus values and an occasional elevation of the alkaline phosphatase [M. L. (L-27)].

Terminally the serum calcium and the serum phosphorus may become depressed [M. K. (R-24)]. The alkaline phosphatase may be elevated or depressed as in patient M. L. (L-27) and in patient C. L. (B-11).

## CASE HISTORIES OF PATIENTS WITH TUMORS (TABLE VIII)

### Patient C. P. (L-8) (Table IX)

Patient M. B. (R-17) was given radium intramuscularly in 1924 (age thirty-six years). In 1948, her right hand became swollen after a minor injury. The condition improved, but the pain and swelling did not com-

TABLE XI

INITIAL SYMPTOMS AND ROENTGENOGRAPHIC CHANGES IN FOURTEEN PATIENTS

| Age (1951) | Time from Administration to Onset of Symptoms (*Years*) | Retained Radium ($\mu$g) | Initial Symptoms | Roentgenographic Changes |
|---|---|---|---|---|
| 51 | 17 | 0.7 | Pain in hip and right leg. | Aseptic necrosis of weight-bearing portion of right femoral head. |
| 56 | 23 | 1.1 | Stiffness and limitation of motion of right forearm. | Aseptic necrosis of right radial head. |
| 45 | 21 | 1.3 | Fracture of femur. | Healed fracture of left femur. |
| 48 | 18 | 1.3 | Onset of pain in left foot. | 1948—Aseptic necrosis of left tarsal navicular.<br>1951—Marked destructive changes of left tarsal bones—fibrosarcoma. |
| 79 | 10–15 | 1.6 | Bone spicules. Frequent episodes of osteomyelitis of left mandible. | Non-union of left mandible. |
| 42 | 9 | 1.6 | Note in Hospital record "old osteochondritis" of femoral heads (1940). Walked with waddling gait in 1950. | Aseptic necrosis of femoral heads. |
| 55 | 20–25 | 1.6 | Bone spicules from mandible. Marked deterioration of teeth. | Areas of increased and decreased density of the mandible. |
| 42 | 10 | 1.9 | Sudden onset of pain in right hip, limping. | Aseptic necrosis of right femoral head. |
| 52 | 20 | 3.6 | Mental patient—onset of limping noted, 1951. Negative examination, 1950. | Mottling of left femoral head. |
| 65 | 13 | 4.2 | Pain in back necessitating Taylor brace. | Biconcavities of T9, T10, T11, and T12; L1 and L3. Healed fracture of right femur. |
| 52 | 24 | 5.6 | Bone spicules from mandible followed by loss of all teeth. | Marked sclerosis of mandible. |
| 76 | 2 | 10.7 | Difficulty with teeth, eventual loss of left mandible. | Left segment of mandible missing—marked resorption in right. |
|  | 20 |  | Onset of pain in left hip with little progression of symptoms. | Aseptic necrosis of weight-bearing roof of the right acetabulum. |
| 67 | 10–15 | 11.3 | Pain in hips with progression until unable to walk. | Almost complete destruction of femoral heads. |
|  | 5–10 |  | Loss of teeth followed by loss of mandible. |  |
| 68 | 15 | 13.9 | "Arthritis" of feet for ten years. | March fracture of metatarsal. |

pletely subside. In October 1949, destructive changes were found in the first right metacarpal on roentgenographic examination. On histological examination of a section from this area changes resembling osteoid osteoma were seen, but no diagnosis was made. The lesion of the metacarpal bone progressed and extended beyond the limits of the cortex in September 1950.

There was roentgenographic evidence of osteogenesis at the site of the original tumor and, in September 1951, a second resection was done. A histological diagnosis of osteogenic sarcoma was made from the operative specimen. By 1952, the patient's general physical condition had deteriorated considerably and a cordotomy was performed because of increasing pain in her left leg. The patient died in July 1952. The estimated retained radium was .8 microgram.

Patient Mrs. A. DeR. (R-18) (Table IX)

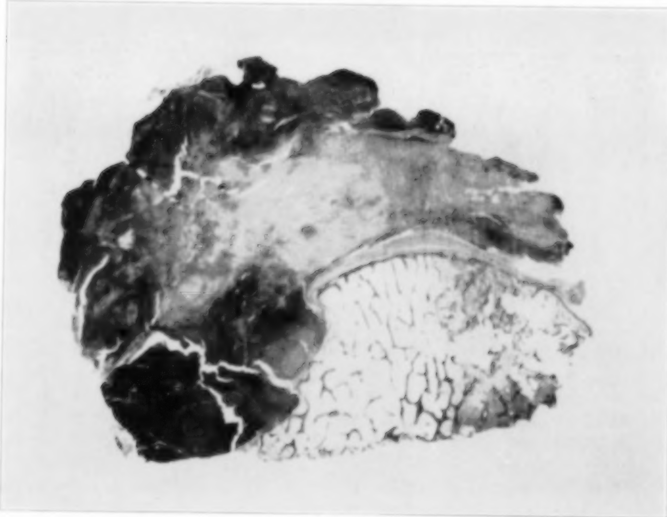


FIG. 13

Photograph of the histological section taken from the tumor area in the tarsal bones of the foot. Note the tumor beginning to invade the cancellous bone. (Courtesy, Dr. C. Howard Hatcher, Department of Orthopaedic Surgery, University of Chicago.)

Patient F. C. (L-15) was employed as a luminous-dial worker from 1917 to 1919 (age seventeen to nineteen years). The patient began to have difficulty with her teeth in 1942. In 1949, a fluctuant mass over the left parietal region was drained. Necrotic material but no neoplastic cells were found. Roentgenograms revealed destructive changes of the left parietal and temporal bones. A mass developed in the left mastoid region which revealed chronic inflammation, fibrosis, and questionable neoplastic cells.

The patient died in 1951, and, at autopsy, a tumor was found in the mastoid region which had invaded the skull. There were adenocarcinoma and epidermoid carcinoma type cells which were thought to have arisen in the accessory nasal sinuses. The estimated retained radium was about one microgram.

Patient M. K. (R-24) (Table IX)

Patient R. W. (L-14) (Table IX)

Patient K. M. (L-16) was employed as a luminous-dial worker from 1921 to 1926 (eighteen to twenty-three years of age). In 1933, swelling of the mandible began, and a year later a spontaneous fracture of the mandible occurred. A diagnosis of giant-cell tumor was made on roentgenographic examination. The patient died in 1934. An autopsy was not performed. The estimated retained radium was 1.5 micrograms.

Patient I. D. (L-21) (Table IX)

Patient C. I. (R-36) was given radium water in 1920 (age forty-seven). In 1929, an abscess of the spine was drained and roentgenograms of the skull, mandible, ribs, and vertebrae revealed changes characteristic of the deposition of radioactive elements. In 1936, her left knee became swollen, and roentgenograms showed a soft-tissue mass in the region of the knee, with destruction of the medial condyle of the femur. A fibrosarcoma of the knee, with generalized metastases, was found on postmortem examination in 1937. The estimated retained radium was six micrograms.

Patient F. R. (L-23) was employed as a luminous-dial worker from 1918 to 1919 (age twenty-one to twenty-two years). In 1944, the patient complained of pain over the lateral condyle of the tibia. She died in 1945 as a result of osteogenic sarcoma arising from the lateral condyle. The estimated retained radium was 6.5 micrograms.

Patient F. W. (R-45) was said to have received radium injections at the age of forty years in 1926. Pain developed in her arm twenty-one years later in 1947. The diagnosis of osteogenic sarcoma of the humerus was made by histological examination one year later. The arm was amputated. Bilateral pleural

## TABLE XII

### Hematological Studies *

| Initials | Estimated Total Body Radium | Date | Erythrocyte Count (*Cubic millimeter*) | Hemoglobin (*Grams per 100 c.c.*) (Photoelectric Method) | Leukocyte Count (*Cubic millimeter*) | Polymorphonuclear Count | Stab Cells | Metamyelocytes Seen in 300 Cells | Lymphocytes | Monocytes | Eosinophils | Basophils | Condition of Red Cells on Differential Count |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| M. H. | .06 | 1/31/51 | 467 | 13.7 | 5650 | 48 | | | 40 | 7 | 5 | | Normal |
| | | 4/27/51 | 424 | 12.6 | | 49 | | | 47 | 2 | 1 | 1 | Normal |
| C. C. | 0.4 | 10/10/51 | 505 | 14.0 | 7700 | 48 | | | 38 | 4 | 9 | 1 | Normal |
| P. N. | 0.5 | 8/29/50 | 491 | 14.5 | 25800 | 84 | 2 | 1 | 10 | 3 | 0 | 0 | Normal |
| | | 5/10/51 | 485 | 13.0 | 12600 | 63 | | | 32 | 2 | 2 | 1 | Normal |
| R. W. | 0.5 | 3/16/51 | 440 | 13.0 | 7700 | 53 | 2 | | 34 | 4 | 6 | 1 | Slight anisocytosis |
| O. W. | 0.5 | 5/10/51 | 487 | 16.0 | 11000 | 68 | | | 26 | 4 | 1 | 1 | Normal |
| A. B. | 0.5 | 9/26/51 | 441 | 13.0 | 4900 | 55 | 1 | 1 | 39 | 5 | | | Normal |
| L. P. | 0.6 | 8/22/50 | 414 | 11.8 | 2800 | 61 | | | 37 | 1 | 1 | | Slight anisocytosis and hypochromia |
| R. M. | 0.6 | 5/9/51 | 448 | 11.7 | 9500 | 58 | 1 | | 32 | 4 | 2 | 2 | Normal |
| H. K. | 0.7 | 10/9/51 | 442 | 14.4 | 7250 | 57 | | | 39 | 3 | 1 | | Normal |
| H. V. | 0.7 | 11/17/50 | 467 | 12.7 | 11200 | 72 | | | 26 | 1 | 1 | | Normal |
| E. A. | 0.8 | 5/10/51 | 406 | 12.5 | 8600 | 67 | 1 | | 25 | 2 | 4 | 1 | Normal |
| C. D. | 0.8 | 8/29/50 | 497 | 16.5 | 17000 | 88 | 1 | | 9 | 2 | | | Normal |
| | | 5/10/51 | 515 | 17.0 | 9600 | 70 | 2 | 1 | 24 | 3 | 1 | | Normal |
| E. J. | 0.8 | 10/16/51 | 385 | 12.0 | 7800 | 72 | 3 | | 23 | 1 | 1 | | Slight anisocytosis and hypochromia |
| G. Z. | 0.9 | 5/9/51 | 431 | 12.2 | 9500 | 52 | 1 | | 44 | 1 | 2 | | Slight anisocytosis, few stippled red blood cells |
| G. N. | 1.0 | 5/9/51 | 435 | 12.5 | 8100 | 53 | 1 | | 33 | 2 | 10 | 1 | |
| D. D. | 1.0 | 8/22/50 | 472 | 14.5 | 12300 | 57 | | | 21 | 3 | 18 | 1 | Normal |
| | | 5/7/51 | 420 | 13.0 | 8400 | 52 | 2 | | 25 | 6 | 15 | | |
| V. McC. | 1.0 | 8/17/50 | 467 | 13.6 | 11800 | 55 | | | 42 | 2 | 2 | | Normal |
| | | 5/7/51 | 445 | 13.6 | 7200 | 75 | 1 | | 23 | 1 | | | Normal |
| G. L. | 1.1 | 4/25/51 | 485 | 15.2 | 7700 | 51 | 3 | 1 | 44 | 1 | 1 | | Normal |
| R. W. | 1.3 | 10/9/51 | 465 | 13.6 | 7700 | 74 | | | 21 | 4 | | 1 | Normal |
| M. K. | 1.3 | 1/11/51 | 374 | 11.2 | 4900 | 59 | 2 | | 36 | 1 | 2 | | Marked anisocytosis, mod. poikilocytosis, slight hypochromia |

---

* 19 patients at Elgin State Hospital; 15 patients in the Chicago area; 2 radium-dial employees. Some of these patients were recorded in the Argonne National Laboratory Report 4666 in 1951.

TABLE XII

| Mitotic Lymphocytes<br>Total Seen | Bilobed Lymphocytes<br>Total Seen | Immature Lymphocytes<br>Total Seen | Slightly Immature Lymphocytes | Atypical Lymphocytes | Degenerating Cells | Cells with Vacuoles | Giant Platelets | Atypical Platelets | Sedimentation Rate<br>1 hr. | Hematocrit<br>Per cent |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Occasional | | | Occasional | | 35.0 | 41 |
| | | 1 | | | | | | | | |
| | | | | | | Eosinophils | | | 40 | 42 |
| 1 | | 1 | | | 1 Lymphocyte | | | | 30.0 | 47 |
| | | 1 | 1 | | | 1 Eosinophil | | | 24.0 | 45 |
| 2 | | 1 | 3 | | | 1 per cent eosinophils | Few | Few | 22.0 | 44 |
| | | | Few | | | 2 Monocytes | | | 6.0 | 46 |
| | | | | | | | 2 | | 45.0 | 43 |
| | | | Rare | | | 1 Lymphocyte | | | 34.0 | 38 |
| | | | 2 | | | 1 Lymphocyte | | | 42.0 | 41 |
| | | | | | | | | | 19.0 | 43 |
| | | | | | | 2 Lymphocytes | | | 27.0 | 39 |
| | | | | | | 2 Eosinophils | | | 47.0 | 37 |
| | | | 4 Polymorphonuclear leukocytes, toxic | | | | | | 35.0 | 47 |
| | | 1 | 2 Polymorphonuclear leukocytes | | 2 Lymphocytes | | | | 20.0 | 47 |
| | | | 1 | | | 1 Lymphocyte | Few | | 20.0 | 41 |
| | 1 | | 3 | 2 (transitionals) | | | | | 42.0 | 41 |
| | | 1 | 2 | | | 2 Eosinophils | Few | | 27.0 | 41 |
| | | | | | | | | | 40.0 | 46 |
| | | | 1 | | | 4 Eosinophils<br>1 Polymorphonuclear leukocyte | | | 48.0 | 41 |
| | | | 1 | | | | | | 42.0 | 44 |
| | | | 3 | | | 1 Lymphocyte | Few | | 29.0 | 42 |
| | | | 2 | | | | | | 12.0 | 48.5 |
| | | | | | | | | | 17.0 | 42 |
| Toxic polymorphonuclear leukocytes | | | | Few | | 1 Lymphocyte with vacuoles | | | 54.0 | 36 |

TABLE XII HEMATOLOGICAL STUDIES * (*continued*)

| Initials | Estimated Total Body Radium | Date | Erythrocyte Count (*Cubic millimeter*) | Hemoglobin (*Grams per 100 c.c.*) (Photoelectric Method) | Leukocyte Count (*Cubic millimeter*) | Polymorphonuclear Count | Stab Cells | Metamyelocytes Seen in 300 Cells | Lymphocytes | Monocytes | Eosinophils | Basophils | Condition of Red Cells on Differential Count |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| W. B. | 1.6 | 4/ 4/51 | 504 | 14.9 | 10000 | 61 | 3 | 1 Basophilic | 30 | 4 | 1 | 1 | Normal |
| M. M. | 1.6 | 4/27/51 | 426 | 13.8 | 6400 | 64 | | | 34 | 1 | 1 | | Normal |
| C. S. | 1.6 | 8/17/50 | 450 | 12.2 | 6700 | 71 | | | 25 | 4 | | | Slight anisocytosis and hypochromia |
| | | 5/ 7/51 | 493 | 12.2 | 10300 | 65 | | | 32 | 1 | 2 | | Slight anisocytosis and hypochromia |
| A. M | 1.8 | 8/17/50 | 435 | 13.2 | 8900 | 58 | | | 38 | 2 | 2 | | Slight anisocytosis and hypochromia |
| | | 5/17/51 | 435 | 13.5 | 6600 | 51 | | | 43 | 2 | 2 | 2 | Slight anisocytosis |
| R. D. | 1.9 | 10/16/51 | 435 | 13.5 | 9800 | 60 | 5 | | 27 | 2 | | | |
| L. W. | 2.6 | 5/10/51 | 440 | 12.9 | 9400 | 69 | 1 | 1 | 26 | 3 | 1 | | |
| F. P. | 2.6 | | | | | | | | | | | | |
| C. L. | 3.6 | 8/22/50 | 424 | 11.5 | 6150 | 55 | 1 | | 46 | 4 | 3 | 1 | Slight anisocytosis |
| | | 5/7/51 | 430 | 12.2 | 8200 | 47 | | | 49 | 2 | 1 | 1 | |
| J. J. | 4.2 | 10/30/51 | 365 | 11.0 | 5300 | 41 | 2 | | 53 | 4 | | | Slight anisocytosis and hypochromia |
| F. J. | 5.4 | 10/30/51 | 425 | 11.5 | 4700 | 66 | | | 28 | 1 | 4 | 1 | Slight anisocytosis |
| D. DeR. | 5.6 | 4/17/51 | 494 | 16.0 | 9750 | 65 | 1 | | 31 | 1 | 2 | | 1 polychromatic red cell |
| D. A. | 6.7 | 5/9/51 | 382 | 11.5 | 7600 | 64 | 1 | | 25 | 2 | 8 | | Moderate anisocytosis and hypochromia |
| A. DeR. | 10.7 | 3/13/51 | 356 | 11.9 | 10600 | 67 | 7 | 1 | 23 | 1 | 1 | 1 | Moderate anisocytosis, slight poikilocytosis and hypochromia |

---

* 19 patients at Elgin State Hospital; 15 patients in the Chicago area; 2 radium-dial employees.

TABLE XII (*continued*)

| Mitotic Lymphocytes Total Seen | Bilobed Lymphocytes Total Seen | Immature Lymphocytes Total Seen | Slightly Immature Lymphocytes | Atypical Lymphocytes | Degenerating Cells | Cells with Vacuoles | Giant Platelets | Atypical Platelets | Sedimentation Rate 1 hr. | Hematocrit Per cent |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 3 | | 3 | | | | | | | |
| | | | | | | 3 Lymphocytes | Few | Few | 13.0 | 52 |
| | | | | | | | | | 32.0 | 43 |
| | | | Few | | | | | | 32.0 | 41 |
| | 1 | | 1 | | | | | | 38.0 | 42 |
| | | | Few | | 1 Lymphocyte | | | | 40.0 | 42 |
| 1 | | | 1 | | | | | | 48.0 | 40 |
| | | | | | | 1 Monocyte | | | 42.0 | 30 |
| | | 3 | Few | | | 1 Lymphocyte | | | 43.0 | 41 |
| | | | 2 | | | | | | 47.0 | 40 |
| 1 Binucleated polymorphonuclear leukocyte | | | | | Few polymorphonuclear leukocytes | | Few | | 41.0 | 39 |
| Several lymphocytes with large azure granules | | | | | | | | | | |
| Toxic polymorphonuclear leukocytes | | | | 2 | | | | | 40.0 | 36 |
| Toxic polymorphonuclear leukocytes | | | | | | | | | 41.0 | 38 |
| | | | | Occasional | | 1 Polymorphonuclear leukocyte | | | 20.5 | 50.5 |
| | | | | | | 1 Monocyte<br>1 Eosinophil | | | 37.0 | 38 |
| Few toxic polymorphonuclear leukocytes | | | 4 | | | Few polymorphonuclear leukocytes and eosinophils, few lymphocytes | | | 38.0 | 35 |

TABLE XII (*continued*)

| Initials | Estimated Total Body Radium | Date | Erythrocyte Count (*Cubic millimeter*) | Hemoglobin (*Grams per 100 c.c.*) (Photoelectric Method) | Leukocyte Count (*Cubic millimeter*) | Polymorphonuclear Count | Stab Cells | Metamyelocytes Seen in 300 Cells | Lymphocytes | Monocytes | Eosinophils | Basophils | Condition of Red Cells on Differential Count |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| M. H. | 11.3 | 5/10/51 | 485 | 14.0 | 7000 | 68 | | | 27 | 4 | 1 | | Normal |
| J. F. | 13.9 | 10/4/51 | 380 | 11.0 | 7000 | 66 | | | 29 | 2 | 2 | | Moderate anisocytosis, slight hypochromia |
| K. B. | | 4/13/47 | 480 | 15 | 8050 | | | | | 3 | 2 | | Slight hypochromia and anisocytosis |
| | | 4/17/49 | 389 | 12.6 | 9680 | 75 | | | | | | | |

effusion developed, and she died a short time later. The patient had nine grams of hemoglobin during her terminal hospitalization. The estimated retained radium was eight to nine micrograms.

Patient M. L. (L-25) was employed as a luminous-dial worker from 1919 to 1924 (nineteen to twenty-four years of age). In 1936, pain developed in the hips, and roentgenographic changes characteristic of the deposition of radioactive elements were present in the pelvis and the femur. In 1937, pain developed over the frontal region and roentgenograms revealed an osteolytic lesion in the petrous portion of the left temporal bone and in the floor of the left middle fossa. In 1938 the patient died of carcinoma of the paranasal sinuses. The estimated radium retained was ten micrograms.

## REPRESENTATIVE CASE HISTORIES (TABLE IX)

C. P. (L-8). Age forty-six; examined on February 27, 1952; retained radium, 0.5 microgram; time interval, thirty years.

In 1922, the patient, sixteen years old, worked as a dial painter for one year. In 1934, twelve years after her employment, pain developed in the region of the left elbow. After three to four months a five-centimeter mass developed in the antecubital space. The arm was disarticulated at the shoulder following the histological diagnosis of fibrosarcoma of the radial head. Since the amputation of the arm, the patient has been in good health except for intermittent pain in the left ankle and the right knee.

Physical examination on February 27, 1952, was non-contributory. On roentgenographic examination, small areas of decreased density were seen in the skull, the humerus, and the femur, and moderately marked changes were seen in the metatarsals, the tibia, and the fibula. One tarsal navicular demonstrated a typical moderately advanced aseptic necrosis.

H. V. (R-13). Age fifty-one; examined on November 17, 1950; retained radium, 0.7 microgram; time interval, twenty years.

This patient had received twelve injections of radium (120 micrograms) in 1928 for a "nervous condition" and depression following the birth of her first child. She had had forty micrograms of radium in 1934 for mental depression following the birth of her second child. In 1949, twenty-one years after the first injection, she began to notice a pulling sensation in the right groin after walking. This was followed by pain in the entire right lower extremity three weeks later. Occasionally the patient was unable to move the leg for two to three minutes. After considerable exercise, low-back pain was noted but this did not seem to have any relation to the pain in the extremity. No other joints were involved. The history was negative for other causes of the pain.

In June 1950, she consulted a physician because of the continuation of the pain with a slight increase in severity. Aseptic necrosis of the right femur was found on roentgenographic examination. The physical examination was negative on November 17, 1950, except for pain and stiffness of the hip following motion of the right lower extremity. Minimal pain was elicited on moving the extremity 20 degrees in the medial direction, 30 degrees in the lateral direction, and 50 degrees on straight-leg raising.

TABLE XII (*continued*)

| Mitotic Lymphocytes Total Seen | Bilobed Lymphocytes Total Seen | Immature Lymphocytes Total Seen | Slightly Immature Lymphocytes | Atypical Lymphocytes | Degenerating Cells | Cells with Vacuoles | Giant Platelets | Atypical Platelets | Sedimentation Rate 1 hr. | Hematocrit Per cent |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | | 2 Lymphocytes | 2 Lymphocytes | | | 32.0 | 44 |
| | | | 1 | | | | | | 46 | 37 |

No other changes were found on complete skeletal roentgenographic examination at that time. The patient was edentulous; the remainder of the examination was essentially negative.

Hematological examination on November 17, 1950, revealed 12.7 grams of hemoglobin per 100 cubic centimeters and 4,670,000 erythrocytes per cubic millimeter. The erythrocyte-sedimentation rate was 39 millimeters in one hour.

A reconstruction operation of the right hip was done in 1951. A segment of the head of the femur was removed and a section of the left fibula was inserted. Very dense, dead bone was found in the area of aseptic necrosis.

Histological sections from the head of the femur and the fibula revealed histopathological changes characteristic of the deposition of radioactive elements. The changes in the fibula were important from a clinical diagnostic standpoint since there was no evidence of change demonstrated on roentgenographic examination before or after the operation. Roentgenographic examination of the patient in 1954, however, revealed areas of decreased density in the fibula and the other long bones, which were characteristic of the deposition of radioactive elements. There was an increase in the severity of the aseptic necrosis of the right femoral head; a moderate degree of aseptic necrosis of the left femoral head had occurred since the examination in 1951.

Mrs. A. DeR. (R-18). Age seventy-four years; examined on February 19, 1951; retained radium, 0.8 microgram; time interval, unknown.

This patient did not remember receiving radium. She was discovered when the roentgenograms of her husband, known to have been given radium, were reviewed by a radiologist who had reviewed this patient's films. The diagnosis of radium deposition was made by the similarity of the roentgenographic changes in the two patients.

In 1947 the patient struck her right leg, and, because of the continued pain, swelling, and lameness, roentgenograms of the tibia were made. A roentgenographic diagnosis of osteomyelitis was made and ten courses of external irradiation were given. There was improvement of the condition following x-ray therapy. The condition was considered to be very suggestive of Ewing's tumor, with multiple myeloma to be ruled out.

Later, in 1947, a biopsy of the tibia was done and a histological diagnosis of osteoid osteoma was made. In 1948, the lesion was curetted, and, at this time, the lesion was considered to be a giant-cell tumor. There was little discomfort following the curettement; however, the patient was unable to bear any weight on the leg.

In 1949, a pathological fracture of the femur was sustained when she fell on her crutches. A high amputation of the limb was done because of the extensive bone involvement and failure of the fracture to heal.

The patient was examined on February 19, 1952. She was a small, thin, alert female, showing rather marked evidence of a chronic illness and weight loss. No pain or discomfort of any of the joints had been experienced since 1948. She had noted pain in the mid-portion of her back to the right of the mid-line since January 1952.

On complete roentgenographic examination, multiple areas of increased density were found throughout

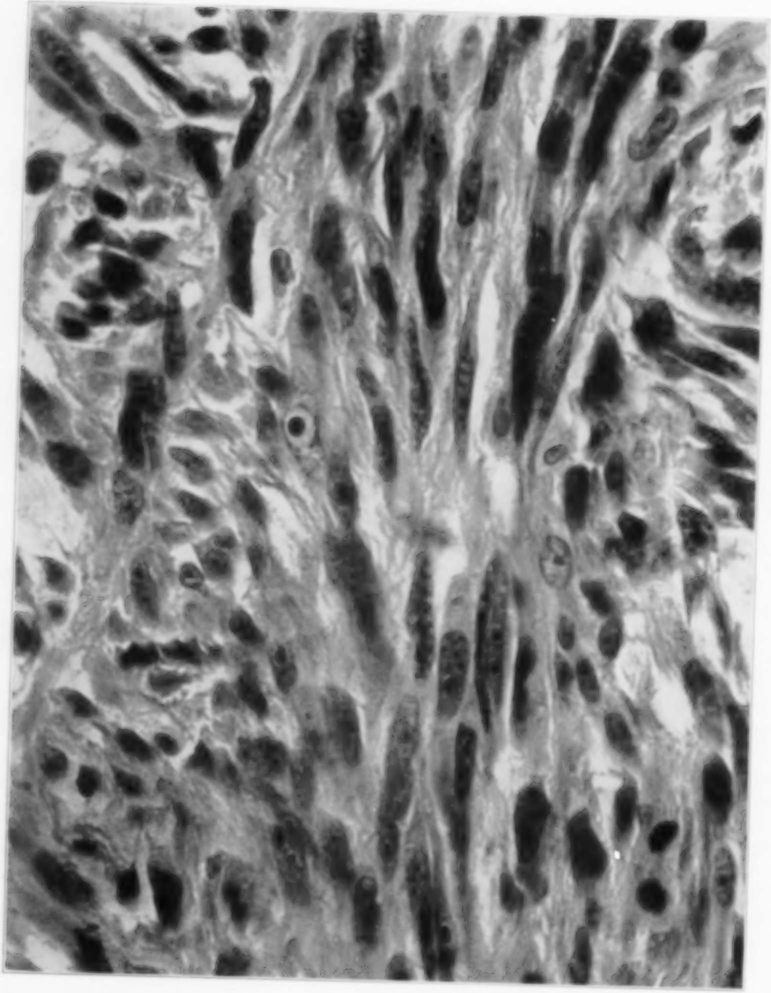


Fig. 14

Photomicrograph of a histological section taken from the fibrosarcoma of the left foot. (Courtesy of the late Dr. Dallas Phemister, Department of Orthopaedic Surgery, University of Chicago.)

the lung fields, suggestive of metastatic osteogenic sarcoma. Erosive changes were present in the ninth rib on the right.

Shortly after the examination rapid dementia occurred either from a cerebral vascular accident or from metastases to the brain. The patient died on October 8, 1952, as a result of what was considered to be generalized metastases from the osteogenic sarcoma (Figs. 6-A, 6-B, 7, 8, 9, and 18).

Review of the histological sections taken in 1947 revealed areas which had begun to undergo malignant change.

Hematological examination on August 24, 1947, revealed: white blood cells, 8,400 per cubic millimeter; red blood cells, 4,030,000 per cubic millimeter; hemoglobin, 12.9 grams per 100 cubic centimeters; polymorphonuclear leukocytes, 70 per cent; lymphocytes, 26 per cent.

Examination on April 17, 1949, revealed: white blood cells, 13,700 per cubic millimeter; red blood cells, 4,440,000 per cubic millimeter; hemoglobin, 13.5 grams per 100 cubic centimeters.

Examination on February 19, 1952, revealed: white blood cells, 10,400 per cubic millimeter; red blood cells, 4,400,000 per cubic millimeter; hemoglobin, 13.5 grams per 100 cubic centimeters; polymorphonuclear

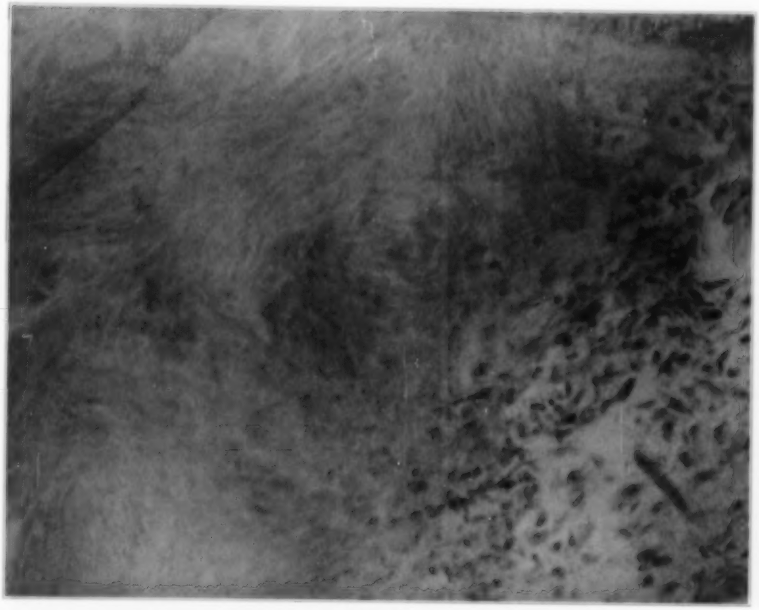


FIG. 15

Photomicrograph of a histological section of the head of the humerus. Note the neoplastic tissue on the left and the fibrous connective tissue on the right. In some instances it was difficult to distinguish between malignant and non-malignant tissue. (Courtesy Dr. C. Howard Hatcher, Department of Orthopaedic Surgery, University of Chicago.)

leukocytes, 74 per cent; stab cells, 1 per cent; lymphocytes, 3 per cent. On examination of a smear, the polymorphonuclear leukocytes appeared slightly toxic.

Examination on August 16, 1952, revealed: white blood cells, 10,000 per cubic millimeter; hemoglobin, 14.0 grams per 100 cubic millimeters; polymorphonuclear leukocytes, 78 per cent; lymphocytes, 16 per cent.

The sedimentation rate on February 19, 1952, was thirty-two millimeters in one hour.

G. L. (R-23). Age fifty-six; examined on May 10, 1951; retained radium, 1.1 micrograms; time interval, twenty-six years.

This patient was given radium for psoriasis in 1925. Pain was first noted in the right elbow in 1949 while the patient was playing golf. There had been some limitation of motion. However, there was minimal increase in the symptoms and no redness or swelling. Pain was elicited by placing the hand over the back of the head. Roentgenographic changes were found in the "right elbow joint" in 1950. On skeletal roentgenographic examination (1951), aseptic necrosis was seen in the head of the right radius. There was minimal mottling of the left head and neck of the femur and slight mottling of the glenoid processes. Minimal streaking was present in the radii and a small area of decreased density was present in the third right cuneiform.

The hematological changes were within normal limits with the exception of an erythrocyte-sedimentation rate of twelve millimeters in one hour.

M. K. (R-24). Age forty-eight; examined on January 11, 1951; retained radium, 1.3 micrograms; time interval, twenty-two years.

At the age of twenty-six, the patient was hospitalized with an illness diagnosed as "subacute bacterial endocarditis" and "polyarthritis". Fifteen to thirty drops of a radium-chloride solution was given orally one to three times daily for several weeks. The patient recovered and the clinical history was uneventful until July 1947, about eighteen years after the administration of radium. The patient noted the sudden onset of pain in the left foot while walking.

The pain and difficulty in walking gradually increased in severity until it became necessary to walk with a cane in 1950. Pain in other parts of the body began to occur and gradually became generalized.

Because of the marked degenerative changes noted in the tarsal bones of the left foot in the three-year period, a biopsy specimen was obtained and fibrosarcoma was diagnosed by histological section. On February 20, 1951, the leg was amputated fifteen centimeters below the knee. The patient made a fairly

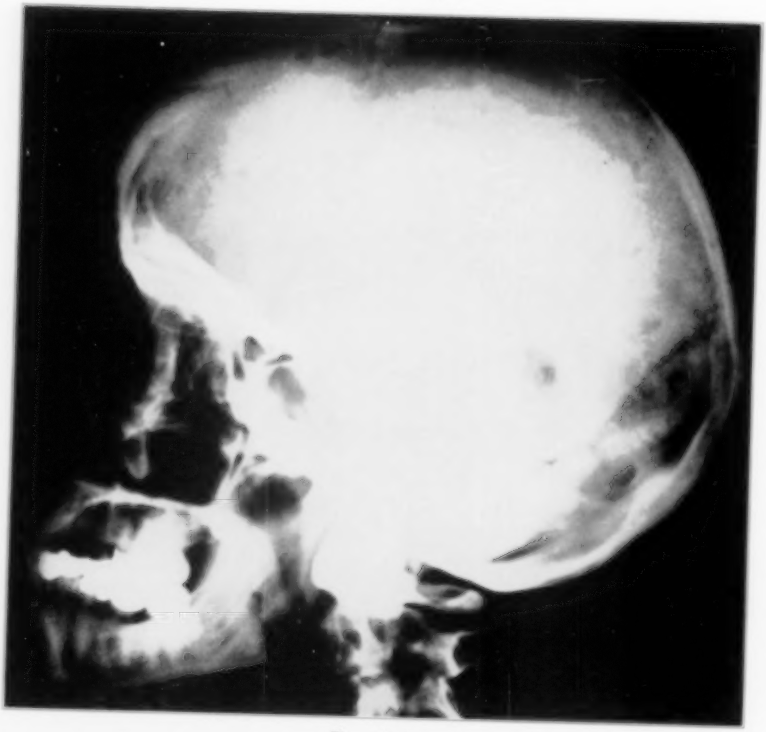


FIG. 16-A

Roentgenogram of the skull of patient M. K. (R-24) made in 1948. Note the area of aseptic necrosis in the left occipitoparietal region. Twelve small areas of decreased density were present.

satisfactory recovery. However, the generalized bone pain continued, and one area on the stump failed to heal. Roentgenograms of the pelvis and stump on May 7, 1951, revealed a rather marked increase in the areas of decreased density. Roentgenograms of the chest were negative. In spite of a transfusion and other therapeutic measures the patient's condition became progressively worse. Larger and larger amounts of analgesics were necessary in order to control the pain. She died on August 15, 1951. An autopsy revealed generalized metastases from the fibrosarcoma.

Roentgenographic examination, in 1948, revealed an area of aseptic necrosis in the left occiptoparietal region and in the left tarsal navicular. There were twelve small areas of decreased density in the skull. Mottling was present in the glenoid processes, heads of humeri, heads and necks of femora, and streaking on the tibiae, ulnae, fibulae, femora, and right radius. Horizontal areas of increased density were found on the anterior and superior surfaces of first, second, third, and fourth thoracic vertebrae, and the pelvis had an abnormal appearance in the trabecular pattern. A complete survey of the skeleton, in 1951, revealed an increase in the frequency of the roentgenographic changes with a small increase in size compared with the changes seen in 1948. For example, the skull had twenty-two areas of decreased density in 1951 compared with twelve in 1948. The tarsal bones of the left foot had undergone marked destructive changes (Figs. 1, 2, 5, 11, 12, 16-A and 16-B).

On dental roentgenographic examination an irregular area of decreased density fifteen by thirty millimeters was found in the region of the ramus of the right mandible, and longitudinal bands of decreased density were found in the same region on the left. A dental examination was not done.

Results of hematological examinations were as follows:

On February 3, 1948: red blood cells, 5,300,000 per cubic millimeter; hemoglobin, 12 grams per 100 cubic centimeters. Smear of peripheral blood showed the polymorphonuclear leukocytes to be toxic.

On January 11, 1951: red blood cells, 3,740,000 per cubic millimeter; hemoglobin, 11.2 grams per 100 cubic centimeters. Smear of peripheral blood showed the polymorphonuclear leukocytes to be toxic.

In July 1951: red blood cells, 3,000,000 per cubic millimeter; hemoglobin 9 grams per 100 cubic centimeters. Smear of peripheral blood showed the polymorphonuclear leukocytes to be toxic.

Results of laboratory examination were as follows:

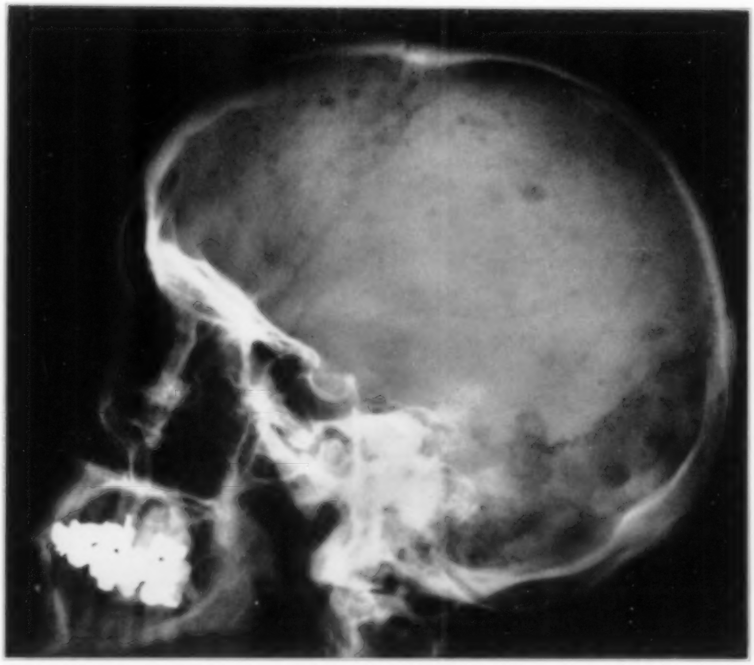


FIG. 16-B

Roentgenogram of the skull of patient M. K. (R-24) made in 1951. There has been almost no increase in the size of the area of aseptic necrosis in the left occipitoparietal region. Twenty-two areas of decreased density are present with increase in size of those seen on roentgenographic examination in 1948. (Courtesy Dr. A. M. Brues, Division of Biological and Medical Research, Argonne National Laboratory.)

On February 6, 1948: serum calcium, 10.3 milligrams per 100 cubic centimeters; serum phosphorus, 5.4 milligrams per 100 cubic centimeters; and alkaline phosphatase, 5.2 Bodansky units.

On February 16, 1948: serum calcium, 10.4 milligrams per 100 cubic centimeters; serum phosphorus, 5.7 milligrams per 100 cubic centimeters; and alkaline phosphatase, 5.3 Bodansky units.

On March 6, 1948: serum calcium, 10.4 milligrams per 100 cubic centimeters; serum phosphorus, 3.3 milligrams per 100 cubic centimeters.

On January 11, 1951: serum calcium, 8.7 milligrams per 100 cubic centimeters; serum phosphorus 3.3 milligrams per 100 cubic centimeters; and alkaline phosphatase, 4 Bodansky units.

The sedimentation rate on January 11, 1951, was 54 millimeters in one hour.

R. W. (L-14). Age forty-five; examined on October 10, 1951; retained radium, 1.3 micrograms; time interval, twenty-seven years.

This patient had been painting luminous dials since 1924, with the exception of one year. The history was uneventful until 1948, when she slipped and fell on the curbing and broke her left femur. Four months later the left femur was rebroken as a result of falling while walking with crutches. One year after the initial fall, the patient was able to return to her employment as a luminous-dial painter. With the exception of minimal swelling of the left foot on warm days, there was no other difficulty until the onset of arthritis of the hands and wrists in 1951. Examination on October 10, 1951, was essentially negative. Minimal hypertrophic changes were observed in the hands. There was an elevated area in the middle of the left thigh as a result of the fracture of the femur. No pain or tenderness was elicited on full range of motion of all joints, with the exception of the left elbow which had been injured when she was a child. On skeletal roentgenographic examination, ten areas of decreased density were present in the skull. There was mottling of the head of the left femur with a slight increase in the density of the superior surface of the left acetabular ridge. A healed fracture was observed in the mid-shaft of the left femur. There was streaking of the radii, ulnae, left fibula, left metatarsals, and the proximal phalanx of the great toe.

Periodontitis, with some pulpless teeth, and dental caries were found on dental examination.

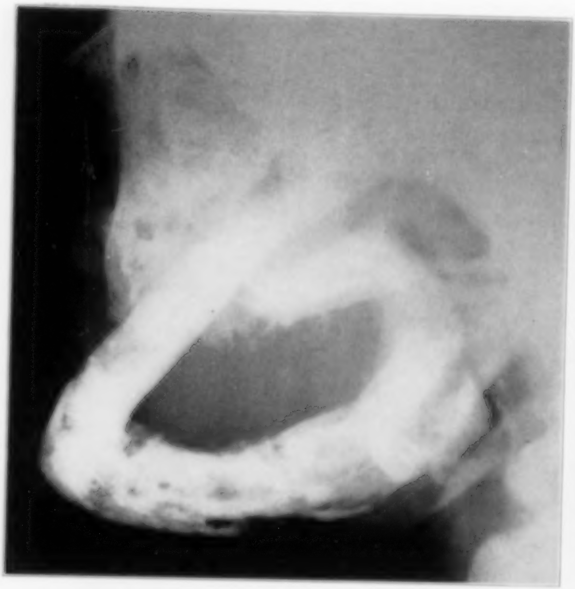


FIG. 17

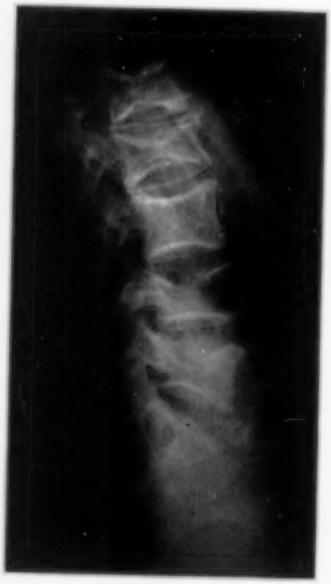


FIG. 18

Fig 17: Roentgenogram of the mandible of patient M. L. (L-27) made in 1951. Note destructive lesion of the mandible, giving a "moth-eaten" appearance. (Courtesy, Dr. W. A. Thomas, Presbyterian Hospital, Chicago, Illinois.)

Fig. 18: Roentgenogram of the lateral view of the lumbar vertebrae of patient A. DeR. Note the biconcavities and the increased density along the superior and inferior borders of the vertebral bodies. (Courtesy, Dr. A. M. Brues, Division of Biological and Medical Research, Argonne National Laboratory.)

The hematological examination was within normal limits with the exception of a sedimentation rate of 17 millimeters in one hour.

Early in 1953, pain developed in the right hip and a large area of decreased density was found, involving most of the body of the ischium. A hemiplevectomy was performed later in the year, and the diagnosis of osteogenic sarcoma was made by histological examination. In 1954, multiple areas of increased density were found throughout the lung fields and a sarcomatous lesion had developed at the site of amputation.

The patient died on July 22, 1954.

C. S. (R-28). Age forty-two; examined on August 17, 1950; retained radium, 1.6 micrograms; time interval, twenty years.

This patient was admitted to the Elgin State Hospital, May 16, 1930, with the diagnosis of dementia praecox (paranoid type). She received ten micrograms of radium chloride weekly for fifteen weeks. Six months after the administration of radium, 8.2 micrograms of radium (5.5 per cent) was estimated to be present in the body, 3.4 micrograms (2.3 per cent) was estimated to be present at twelve months, and 1.6 micrograms (1.1 per cent) at twenty years (1951).

In 1940, a diagnosis of "old osteochondritis" of the femora was made after roentgenographic examination. No further information concerning the condition was present in the patient's record. In examination, on August 17, 1950, the patient was observed to walk with a waddling gait with little discomfort. She was well developed and well nourished, with some mental deterioration. There was slight limitation of motion of the hip joints and minimal pain on pressure over the spine. The rest of the examination was essentially negative.

Minimal mottling of both humeri and the pelvis, with questionable mottling of the left glenoid process, was found on skeletal roentgenographic examination. On the anterior surface of the eighth thoracic vertebra and the anterior superior surface of the third thoracic vertebra, there were horizontal areas of increased density one centimeter in the greatest dimension. Marked aseptic necrosis of the heads of the femora was found.

There was poor oral hygiene. There were several large maxillary restorations and several missing teeth. The dental roentgenographic examination was essentially negative.

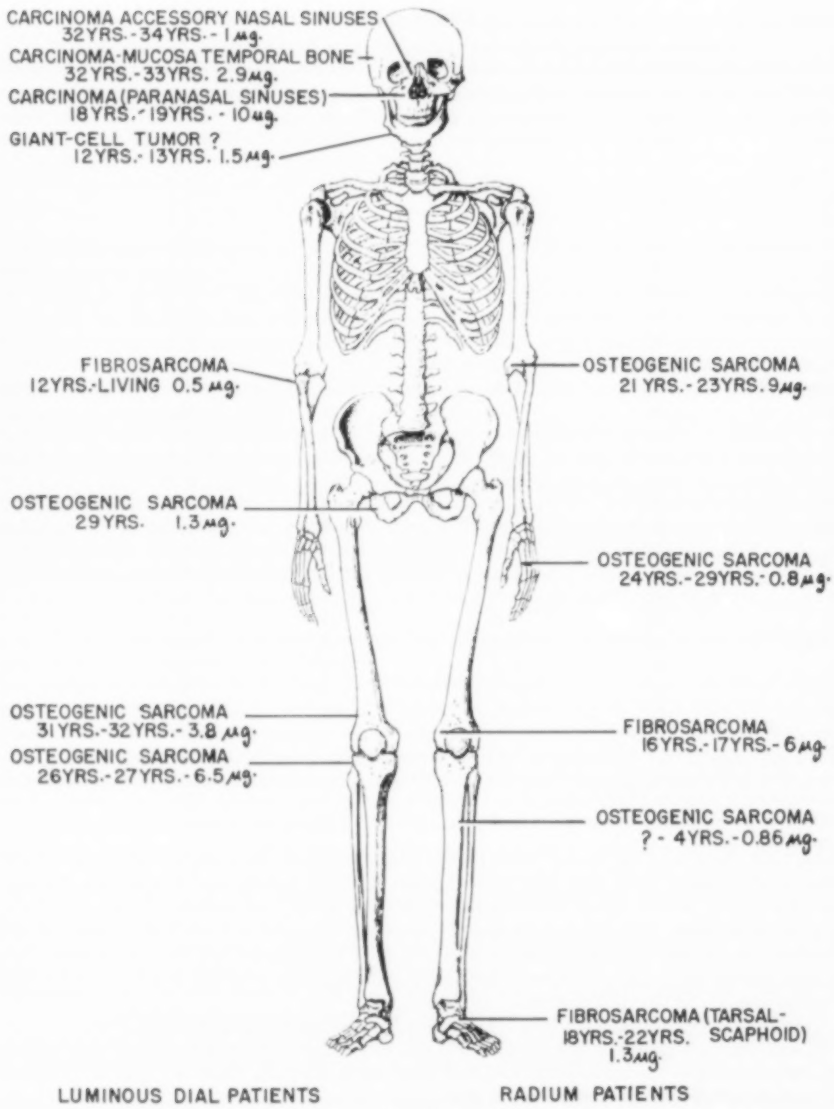

CARCINOMA ACCESSORY NASAL SINUSES
32YRS.-34YRS.- 1µg.
CARCINOMA-MUCOSA TEMPORAL BONE
32YRS.-33YRS. 2.9µg.
CARCINOMA (PARANASAL SINUSES)
18YRS.-19YRS. - 10µg.
GIANT-CELL TUMOR ?
12YRS.- 13YRS. 1.5µg.
FIBROSARCOMA
12YRS.-LIVING 0.5µg.
OSTEOGENIC SARCOMA
21 YRS.- 23YRS. 9µg.
OSTEOGENIC SARCOMA
29YRS. 1.3µg.
OSTEOGENIC SARCOMA
24YRS.-29YRS.- 0.8µg.
OSTEOGENIC SARCOMA
31YRS.-32YRS.- 3.8µg.
OSTEOGENIC SARCOMA
26YRS.-27YRS.- 6.5µg.
FIBROSARCOMA
16YRS.-17YRS.- 6µg.
OSTEOGENIC SARCOMA
? - 4YRS.-0.86µg.
FIBROSARCOMA (TARSAL-SCAPHOID)
18YRS.-22YRS.
1.3µg.
LUMINOUS DIAL PATIENTS
RADIUM PATIENTS

FIG. 19

Tumor formation in patients in Boston and Chicago Investigations (1951). The five tumors which developed in the fifty patients who had received radium are shown on the right side of the skeleton and the eight tumors which developed in twenty-eight luminous-dial painters are shown on the left side of the skeleton. Two more tumors have developed in the patients who had received radium medically. These are not included. The type of tumor, the time from deposition to occurrence of symptoms, the time from deposition to death, and the amount of radium are given in each case. Reading from top to bottom the numbers of the luminous-dial workers are 15, 20, 25, 16, 8, 14, 21, and 23 (Table II); the numbers of the radium patients are 45, 17, 36, 18, and 24 (Table I).

On hematological examination in 1950 and 1951 slight hypochromia and anisocytosis were found in the erythrocytes. The hemaglobin was 12.5 grams per 100 cubic centimeters, the erythrocyte count was 4,500,000 per cubic millimeter, and the sedimentation rate 41 millimeters in one hour.

W. B. (R-26). Age seventy-nine; examined on April 4, 1951; retained radium, 1.6 micrograms; time interval, questionable.

This patient does not remember having receiving radium. In March 1939, a small spicule of bone was

TABLE XIII

SERUM CALCIUM, PHOSPHORUS, AND ALKALINE PHOSPHATASE VALUES *

| Patient | Age (1951) | Est. Total Body Radium (*Micrograms*) | Serum Calcium | Serum Phosphorus | Alkaline Phosphatase |
|---|---|---|---|---|---|
| M. H. | 63 | .06 | 9.5 | 3.7 | 4.5 |
| P. N. | 43 | .50 | 11.3 | 3.2 | 4.7 |
| O. W. | 47 | .50 | 8.6 | 3.1 | 4.7 |
| R. W. | 42 | .50 | 10.2 | 3.3 | 0.7 |
| R. M. | 48 | .60 | 9.5 | 3.9 | 2.9 |
| E. A. | 48 | .80 |  | 3.2 |  |
| C. D. | 53 | .80 | 10.1 | 3.3 | 6.3 |
| H. V. | 51 | .70 | 9.9 | 2.3 | 2.2 |
| G. Z. | 42 | .90 |  | 3.2 | 2.7 |
| G. N. | 45 | 1.0 | 9.5 | 3.8 | 3.1 |
| V. McC. | 51 | 1.0 | 9.6 | 4.9 | 1.7 |
| G. L. | 56 | 1.1 | 9.7 | 2.7 | 3.6 |
| D. D. | 52 | 1.0 | 10.1 | 3.4 | 2.0 |
| M. K. | 46 | 1.3 | 8.7 | 3.3 | 4.0 |
| W. B. | 45 | 1.6 | 10.3 | 3.0 | 9.3 |
| M. M. | 55 | 1.6 | 10.4 | 4.0 | 3.0 |
| C. S. | 42 | 1.6 | 9.7 | 4.1 | 2.1 |
| A. M. | 50 | 1.8 | 10.2 | 4.6 | 3.3 |
| L. W. | 43 | 2.6 | 10.2 |  |  |
| C. L. | 52 | 3.6 | 9.7 | 3.1 | 3.7 |
| D. DeR. | 52 | 5.6 | 11.4 | 3.0 | 1.6 |
| D. A. | 55 | 6.7 | 9.2 | 4.2 | 2.6 |
| A. DeR. | 76 | 10.7 | 9.9 | 3.1 | 2.8 |
| M. H. | 67 | 11.3 | 9.6 | 3.8 | 6.3 |

* Determination at the University of Chicago Clinics (ANL 4666, July 1951). Normal values: serum calcium, 9 to 10 milligrams per 100 cubic centimeters; phosphorus, 2.5 milligrams per 100 cubic centimeters (approximately); alkaline phosphatase, 2 to 4 Bodansky units.

extruded from the gum at the base of the left lower molar, and there was a slight tenderness, redness, and swelling in this region. From that time until October 1940, the patient had intermittent drainage and sequestration from the left ramus of the mandible; this was usually accompanied by malaise, fever, and cervical-gland abscesses. Non-union of the mandible eventually occurred as a result of the repeated episodes of osteomyelitis. On June 17, 1941, the defect of the mandible was repaired with bone transplanted from the right ilium. On October 5, 1941, the infected and necrotic bone graft was removed. Non-union of the mandible was still present at the time of examination on April 4, 1951.

A review of roentgenograms made in 1941 and 1942 demonstrated the mandibular defect.

Skeletal roentgenographic examination in 1951 revealed aseptic necrosis of the fourth right metacarpal. There were mottling of the left femoral head and streaking of the radii, ulnae, tibiae, and fibulae. Several areas of decreased density were found in the skull.

The hematological findings were within normal limits, and the sedimentation rate was 13 millimeters in one hour.

R. D. (R-30). Age forty-one; examined on October 16, 1951; administered radium, 200 micrograms; retained radium, 1.9 microgram; time interval, twenty-one years.

The patient was admitted to the Elgin State Hospital on December 7, 1930, with a diagnosis of manic depressive psychosis. In 1931, ten micrograms of radium chloride was given weekly for twenty weeks. In 1951, 1.9 microgram of radium (1 per cent of the administered dose) was found to have been retained.

Through the years, there were about fifteen readmissions to the mental institution during the manic phases of her mental illness. In 1940, the patient noted the sudden onset of pain in the right hip and right leg. Shortly afterward, the condition progressed until it necessitated limping. There was minimal progression of symptoms except for one exacerbation for two to three months. There is little disturbance in walking following the use of corrective shoes.

The patient was examined on October 16, 1951. She was very alert and cooperative, and walked with a limp of the right leg. Some scoliosis of the thoracic spine was present. There was a full range of motion of all joints except in the right hip. Motion in the medial and lateral planes was limited; however, no difficulty or pain on movement of the hip or other joints of the right lower extremity was experienced.

On skeletal roentgenographic examination there was marked aseptic necrosis of the right femoral head. There was mottling of the left femoral head, left tarsal navicular and left calcaneus, and there was streaking of the right ulna, the radii, the tibiae, and the fibulae. The right tarsal navicular and third right cuneiform bone had an area of decreased density approximately five by five millimeters in size.

Dental examination was not done.

Hematological examination was within normal limits except for a sedimentation rate of 42 millimeters in one hour.

K. B. (R-43). Age sixty-six; examined on April 13, 1947; retained radium, 2 to 10 micrograms; time interval, twenty-five years.

The patient received twelve injections of radium chloride intravenously (probably 120 micrograms) in 1922 as a tonic. The retained radium estimated by urinary values was between 2 and 10 micrograms in 1947.

In 1944, the patient had noted the development of arthritis, which gradually involved the right hip and both knees. By 1946, the patient was bedridden most of the time, as a result of the skeletal changes. Roentgenographic examination at this time demonstrated changes in the long bones and the pelvis which were characteristic of radium deposition.

On April 13, 1947, she was hospitalized with the principal complaints of inability to concentrate and inability to speak correctly. There was a gross irregularity of the cardiac rate, with a blood pressure of 205 systolic and 110 dystolic. The patient was given digitalis and was discharged, much improved, May 19, 1947. The erythrocyte count was low and the sternal marrow on April 18, 1947, was considered to be extremely atrophic. The patient died later in the year from multiple causes. An incomplete skeletal roentgenographic survey made during the hospitalization revealed marked aseptic necrosis of the head of the right femur, moderate necrosis of the left calcaneus, collapse of the eighth and twelfth thoracic vertebral bodies, fragmentation of the left patella, mottling of the head of the femur, and streaking of the tibiae and fibulae.

C. L. (R-34)*. Age fifty-two; examined on August 22, 1950; administered radium, 410 micrograms (1930); retained radium, 3.6 micrograms (twenty years).

This patient was admitted to the Elgin State Hospital in January 1930 with a diagnosis of dementia praecox (catatonic type). In 1930, she received 10 micrograms of radium chloride weekly for forty-one weeks. In 1951, 3.6 micrograms (0.9 per cent of the administered dose of radium) was found to be present in the body.

In 1933, the condition of the teeth was reported as good. She was edentulous on examination in 1950. The remainder of the clinical examination was essentially negative. Between 1950 and 1951, the patient developed a slight limp in the left lower extremity.

On skeletal roentgenographic examination, there was mottling of the heads of the femora (Fig. 3) and streaking of the fibulae, humeri, tibiae, and the right radius. Six small areas of decreased density were present in the skull. Horizontal areas of increased density were present on the anterior articular surfaces of the seventh to twelfth thoracic vertebrae. Small areas of increased density were present in the bodies of the eleventh and twelfth thoracic vertebrae.

There was marked bilateral decrease in density in the bones of the right and left mandible, with almost no trabecular pattern seen on dental roentgenographic examination.

Hematological studies were made in 1950 and 1951. There were 12 grams of hemoglobin per 100 cubic centimeters and 4,300,000 erythrocytes. Several lymphocytes were present, with large azure granules, and a few giant platelets were found. There was slight anisocytosis of the erythrocytes. The sedimentation rate was 47 millimeters and 41 millimeters in one hour in 1950 and 1951, respectively.

I. D. (L-21). Age twenty-seven; examined on February 12, 1951; retained radium, 3.8 micrograms; time interval, thirty years.

This patient was employed for two months as a luminous-dial worker at the age of fifteen years (1921). In 1932, the onset of a dull pain occurred in the calves of the legs which was followed by a knife-like pain in the left hip. A diagnosis of tuberculosis of the hip was made, and she was placed in a cast for five months. She was pregnant at the time, and, following the delivery, there was almost complete relief of pain for almost ten years. In 1945, pain began in the right hip and this was followed by limping and pain on pressure. The right femoral head was replaced with a Vitallium cap; however, it was necessary to remove the cap eighteen months later. In October 1951, the left femur was broken while she was walking on crutches; the femur was broken again in January 1952. There was a deep, boring pain in the left thigh, left leg, and right arm. It was always present, but it seemed to grow worse as the day progressed. Intermittently, the pain became generalized.

In August 1950, the patient was given ACTH for three weeks. After one week the patient was able to raise both lower extremities off the bed. She had been unable to do this for a number of years. This improvement subsided immediately after the ACTH was stopped. She was examined on February 12, 1952, and was found to be unable to walk.

---

* An osteogenic sarcoma of the proximal end of the right tibia has developed since this report was written.

There was no apparent distress of the time of the examination. Tenderness on deep pressure was elicited over the tenth, eleventh, and twelfth thoracic vertebrae, the humeral shafts, left leg, and the forearms, to a lesser degree. The pain was dull in character. There was full range of motion of the shoulder, elbow, and wrist joints. The right leg could be flexed at the knee to 45 degrees with difficulty. A moderate anaemia was present.

Later in the year, pain began in the left knee. Roentgenograms were suggestive of a neoplasm of the medial condyle of the left femur. The leg was amputated and an osteogenic sarcoma was found on histological examination of the tissue (Fig. 10). The patient became more and more debilitated, and she died in January 1953.

In 1947, the patient began to have difficulty with her teeth. The teeth became "sore and achy", with pain over the mandible. Many of the teeth were extracted subsequently with much difficulty. They were so fragile that they usually broke before extraction. There was one remaining upper tooth and five present in the mandible; the base of the lower teeth had a darkened appearance.

Serial roentgenograms over the period 1948 to 1952 revealed a gradual increase in the characteristic skeletal changes due to deposition of radioactive elements. The head and neck of the right femur were completely missing and there was minimal aseptic necrosis of the left humeral head. There was a marked mottling of the heads of the humeri and femora and streaking of the radii, ulnae, tibiae, and fibulae. Areas of decreased density were present in the skull. There were areas of increased density at the metaphyseal-diaphyseal junction of the tibiae, radii, and ulnae.

Hematological examination on January 9, 1952, revealed 12 grams of hemoglobin per 100 cubic centimeters and 3,820,000 erythrocytes per cubic millimeter. The erythrocyte-sedimentation rate was not obtained and the differential count was within normal limits.

J. J. (R-35). Age sixty-six; examined on October 30, 1951; retained radium, 4.2 micrograms; time interval, twenty-two years.

This patient drank radon water in 1922 and 1923. In 1929, she was given radium chloride for an intermittent tachycardia. Approximately 400 micrograms was given over a period of two to three years.

Four years ago, the patient caught her heel on a stairway, fell, fractured her right femur and right ulna, and was on crutches for fourteen weeks. Six years ago severe pain developed in the back. The patient was told that she had "insufficient calcium in her back". A Taylor brace was worn for two years and only minimal discomfort was experienced since that time.

A healed fracture was present in the shafts of the right femur and the right ulna. Minimal aseptic necrosis was found in the right humeral head, and there was fragmentation of the radial heads. There were multiple areas of decreased density in the skull. Mottling was present in the heads and shafts of the humeri, the femora, the glenoid processes, and the metatarsals. Streaking was present in the ulnae, radii, tibiae, and fibulae. The ninth, tenth, eleventh, and twelfth thoracic and the first and third lumbar vertebrae had biconcavities.

The dental examination and dental roentgenographic examination were essentially negative. Hematological examination revealed 11 grams of hemoglobin per 100 cubic centimeters and 3,650,000 erythrocytes per cubic millimeter. The erythrocytes were hypochromic with some anisocytosis. The differential count was within normal limits and the sedimentation rate was 40 millimeters in one hour.

M. L. (L-27). Age forty-nine; examined on September 14, 1951; retained radium, 10 micrograms; time interval, thirty years.

Patient worked as a radium-dial painter from the ages of nineteen to twenty-five years (1921–1927).

In 1937, ten years after leaving the plant, she fell down the steps and suffered a "greenstick" fracture of her left femur, which went unrecognized until the bone snapped while she was bending over several days later. Eleven months later (age thirty-six) she fractured her right femur while picking up her child. In 1945 (age forty-two) she refractured her left femur while pressing her foot to the floor of an automobile during a quick stop. All of these fractures eventually healed.

In 1946 while undergoing teeth extractions, the patient had swelling of the left lower jaw with a discharge of a yellow exudate. Since the fall of 1950, she states that she had had "bone slivers" sloughing from her jaw from time to time.

Arthritis, which began as a painful, tender swelling of the joints of her right hand, occurred in September 1949. Her right wrist became painful and stiff and then her right elbow. This extended to the bones of her forearm and then to her shoulder. Since the fall of 1950, she had not used her right arm and shoulder. She carried her arm in a sling from time to time and she stated that it had decreased in size. The intense pain in the arm required more and more analgesics to control.

In 1951, cortone was given orally with some relief of elbow pain and stiffness in her right arm, but with no effect on the hand and wrist.

In September 1951, the patient was hospitalized because of a paralytic bladder. Various measures failed to alter her downhill course, and she expired September 28, 1951. No specific changes were noted at autopsy (Figs. 4 and 17).

Estimation of the retained radium was not made. Radiochemical analysis of bone specimens from the vertebrae, ribs, and ilium of the patient was done. Comparison of the radium content of these bones with those of other patients in whom the total body content of radium is known indicates that the patient had about 10 micrograms.

Roentgenograms were made of the pelvis, mandible, right humerus, ulna, and radius. There were healed fractures of both femora below the lesser trochanters and beginning mottling of the left femoral head. The iliac wings had irregular areas of increased density. Mottling was present in the humeral head and glenoid process and streaking in the shaft of the humerus, radius, and ulnae which was more marked at the distal ends. The mandible had irregular areas of bone resorption and increased densities which appeared to be lying free just above the alveolar ridge.

The laboratory data demonstrated the hematological changes late in the course of the disease.

Hematological examination revealed:

On May 7, 1951: red blood cells, 4,700,000 per cubic millimeter; hemoglobin, 12.5 grams per 100 cubic centimeters; white blood cells, 9,200 per cubic millimeter; segmented cells, 55 per cent; stab cells, 6 per cent; lymphocytes, 39 per cent.

On May 14, 1951: red blood cells, 3,360,000 per cubic millimeter; hemoglobin, 11 grams per hundred cubic centimeters; white blood cells, 10,350 per cubic millimeter; segmented cells, 74 per cent; stab cells, 6 per cent; lymphocytes, 20 per cent.

On September 15, 1951: red blood cells, 3,270,000 per cubic millimeter; hemoglobin, 10 grams per 100 cubic centimeters; white blood cells, 6,500 per cubic millimeter; segmented cells, 75 per cent; stab cells, 5 per cent; and lymphocytes, 17 per cent.

Alkaline phosphatase estimation was done on May 9, 1951; there were 19 Bodansky units.

A. DeR. (R-44). Age seventy-six; examined on March 13, 1951; retained radium, 10.7 micrograms; time interval, twenty years.

This patient received two ampules of radium weekly for approximately nine months in about 1931. The physician who gave the radium stated that he almost always gave ten-microgram ampules. If we assume this to be true, the patient was given between 700 and 800 micrograms of radium.

He began to have difficulty with the mandible about two years after being given radium. Over a period of years all of his teeth, as well as the anterior one-half of the mandible, were lost. In 1949, he began to experience an "arthritic type" of pain in the right hip. There was only slight progression of the pain with minimal stiffness and limitation of motion of the leg at the time of the examination in 1951. The patient was hospitalized for an ear infection. Three transfusions were given at that time. On physical examination he was found to be thin and emaciated. The facial features were distorted by the loss of the mandible, and his gait was slow, with a limp of the right leg.

He was reexamined on February 19, 1952, and found to have some increase in the generalized weakness and pain in the right hip. There was a dull pain with an occasional sharp knife-like pain which was aggravated by motion. Stiffness had increased to such a degree that it was difficult to get his clothes on and off. Marked diminution of the pain and stiffness of the right leg occurred after being placed on cortisone for three weeks.

Draining of the right ear occurred, which was followed by pain over the face and right side of the head. He was hospitalized October 29, 1952, for extreme weakness and emaciation. Hospital records stated that the history was not obtainable because of deafness and cerebral sclerosis. The patient's condition gradually deteriorated and he died January 8, 1953, with the diagnosis of aplastic anaemia.

Skeletal roentgenographic examination April 13, 1951, revealed aseptic necrosis of the left glenoid process and the weight-bearing portion of the right acetabulum with a central sequestrium measuring 2.5 centimeters. There was partial collapse of the bodies of the fifth, ninth and eleventh thoracic vertebrae. Biconcavities were present in the first, second, fourth, and fifth lumbar vertebrae. Mottling was present in the glenoid processes, heads of the humerii, heads and necks of the femora, and streaking of the radii, ulnae, tibiae, fibulae, femora, and metacarpals. The trabecular pattern of the pelvis had an abnormal appearance. Roentgenograms of the face and head in 1952 revealed areas of increased and decreased density, characteristic of the deposition of radioactive elements.

The patient was edentulous. There was a segment of the left mandible missing.

M. H. (R-47). Age sixty-seven; examined on May 11, 1951; retained radium, 11.3 micrograms; time interval, thirty-one years.

The patient vaguely remembers that radium was given in about 1920 to 1925. In about 1935, she began to have pain in the hips. Pain progressed until she was unable to walk. About 1940, she began to have difficulty with her teeth, and all of her teeth were lost, as well as a large portion of her mandible.

The patient was examined on May 11, 1951. She was an obese, well-developed female whose facial features were distorted as the result of the loss of the mandible. She was able to move the lower extremities only a small amount with difficulty. No pain was elicited by motion or deep pressure over the hip joints. There was a rather long depression in the spine at eighth and ninth thoracic vertebrae and pain occurred if the pressure of a pillow was not present. There was no limitation of motion of the remainder of the joints.

A partial skeletal x-ray survey was made in 1948. This revealed complete destruction of the femoral heads; skeletal changes characteristic of radium toxicity were found in all the roentgenograms available. There was mottling of the right glenoid process and streaking of the fibulae and tibiae.

The mandible was missing and only three upper teeth remained. Dental roentgenographic examination was not done.

The hematological examination was within normal limits with the exception of a sedimentation rate of thirty-two millimeters in one hour.

J. F. (R-49). Age sixty-eight; examined on October 4, 1951; retained radium, 13.9 micrograms; time interval, twenty-five years.

The patient had received about twenty-five injections of radium at weekly intervals twenty-five years ago to "pep him up". During the past ten years "arthritis" affected the feet, knees, and right shoulder. In May 1950, the patient suffered right hemiplegia from which he made a satisfactory recovery. There were minor changes characteristic of the deposition of radioactive elements found on skeletal roentgenographic examination. Minimal changes were found in the thoracic vertebrae, radius, ulna, fibula, tibia metatarsals, and the phalanges of the feet.

There were eleven grams of hemoglobin per 100 cubic centimeters and 3,800,000 erythrocytes per cubic millimeter on hematological examination on October 4, 1951. The erythrocytes were slightly hypochromic with moderate anisocytosis. The sedimentation rate was forty-six millimeters in one hour.

## REFERENCES

1. Aub, J. C.; Evans, R. D.; Gallagher, D. M.; and Tibbet, D. M.: Effects of Treatment on Radium and Calcium Metabolism in the Human Body. Ann. Int. Med., **11:** 1443–1463, 1938.
2. Aub, J. C.; Evans, R. D.; Hempelmann, L. H.; and Martland, H. S: The Effects of Internally Deposited Radioactive Materials in Man. Medicine, **31:** 221–239, 1952.
3. Bennett, G.: Personal communication.
4. Bloom, M. A., and Bloom, W.: Late Effects of Radium and Plutonium on Bone. Arch. Pathol., **47:** 494–511, 1949.
5. Chandler, F.: Personal communication.
6. Clark, J.: Personal communication.
7. Davis, Joseph: Personal communication.
8. Fell, E. B.: Personal communication.
9. Hasterlik, R. J.: Personal communication.
10. Hatcher, C. H.: Personal communication.
11. Hempelmann, L. H.; Lisco, H.; and Hoffman, J. G.: The Acute Radiation Syndrome. Ann. Int. Med., **36:** 282–510, 1952.
12. Hodge, P. C.: Personal communication.
13. Johnson, L. C.: Personal communication.
14. Liebon, A. A.; Warren, S.; and DeCoursey, E.: Pathology of Atomic Bomb Casualties. Am. J. Pathol., **25:** 853–1027, 1949.
15. Looney, W. B.: Radium Toxicity Program. A Progress Report of Clinical Studies on Twenty-four Patients. Argonne National Laboratory, ANL 4666, 1951.
16. Looney, W. B., and Woodruff, L. A.: Investigation of Radium Deposition in Human Skeleton by Gross and Detailed Autoradiography. A.M.A. Arch. Pathol., **56:** 1–12, 1953.
17. Looney, W. B.; Hasterlik, R. J.; Brues, A. M.; and Skirmont, E.: The Clinical Investigation of the Chronic Effects of Radium Salts Administered Therapeutically, 1915–1930. Am. J. Roentgenol., **73:** 1006–1037, 1955.
18. Martland, H. S.: Occupational Poisoning in Manufacture of Luminous Watch Dials. General Review of Hazard Caused by Ingestion of Luminous Paint with Special Reference to the New Jersey Cases. J. Am. Med. Assn., **92:** 466–473, 1929.
19. Martland, H. S.: The Occurrence of Malignancy in Radioactive Persons. Am. J. Cancer, **15:** 2435–2516, 1931.
20. Martland, H. S.; Conlon, P.; and Knef, J. D.: Some Unrecognized Dangers in the Use of and the Handling of Radioactive Substances. With Special Reference to the Storage of Insoluble Products of Radium and Mesothorium in the Reticulo-Endothelial System. J. Am. Med. Assn., **85:** 1769–1776, 1925.
21. Potter, R. M.: Personal communication.
22. Ross, P. E.: Personal communication.
23. Soefield, H.: Personal communication
24. Squire, Faye: Personal communication.

# AN IMPROVED PROSTHESIS FOR A SYME AMPUTATION

BY REX L. DIVELEY, M.D., AND RICHARD H. KIENE, M.D., KANSAS CITY, MISSOURI

*From the Dickson-Diveley Clinic, Kansas City*

A Syme amputation, which is the most conservative below-the-knee amputation and which provides the best functioning stump for weight-bearing, has been rarely recommended for women, because the unsightly prosthesis is objectionable.

Some time ago it was necessary to amputate the foot of a female patient, twenty-two years old. After a conference with the young woman, it was decided that the many merits of a Syme amputation far outweighed the objection of the unattractive prosthesis, and an amputation of the Syme type was carried out. A very good stump was obtained, and it was fitted with the conventional prosthesis. Although the artificial limb was most serviceable, it was indeed unsightly and our patient was very unhappy. The problem of finding a more pleasing prosthesis was discussed with our limb maker and, after several attempts, a very neat, light, and functional prosthesis was constructed from laminated plastic material reinforced with glass cloth. After the first lamination or molding, a window was cut out of the back of the prosthesis sufficiently large to allow the stump to slip completely into the socket. Following the last lamination, the open area was closed with a leather lacer.

Although the stump had the usual bulbous end, it was possible to make the bulge less apparent by the proper build-up of the shin portion of the prosthesis and by thinning the plastic material in the region of the malleoli during the laminating process.

## DETAILS OF PREPARATION [1]

A plaster-of-Paris mold of the stump is made extending to the knee and closed distally. From this mold an exact model of the stump is made in the usual way with the usual vented tube incorporated to serve as a handle at the upper end. The landmarks and the plumb-line are redrawn on the model with an indelible pencil. Additional plaster cream is used to accentuate bony prominences and sensitive areas. The model is then thoroughly dried at 140 degrees Fahrenheit and coated with a plastic parting agent to keep the mold from adhering to the model.

Two layers of stockinet are drawn tightly over the model and carefully stitched about the distal end; next, glass cloth is added as reinforcement in the upper and lower thirds. Three more layers of stockinet are then drawn tightly over the model and tied about the handle.

A polyvinyl alcohol sheet is formed into a bag over a template in the usual manner. The bag is then stretched over the model and the proximal end is tied tightly around the handle. Plastic resin is poured into the open end of the polyvinyl alcohol bag and is forced into the layers of stockinet as the cone-shaped bag is pulled proximally over the model. The forcing of the resin into the stockinet is facilitated by massaging the bag toward its proximal end. All wrinkles are pressed out and all air is forced out of the stockinet. Mixed styrene polyester resins are used in the proportion of one-half rigid and one-half flexible.

The polyvinyl alcohol bag is then tied tightly over the distal end of the mold, and curing is effected at 130 to 140 degrees Fahrenheit for about thirty minutes. After the resin has jelled, the final cure is effected at 250 degrees Fahrenheit for approximately thirty minutes.

The top of the mold is trimmed and the plaster model is removed while the mold is

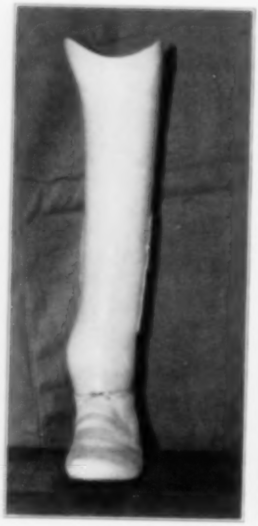


FIG. 1

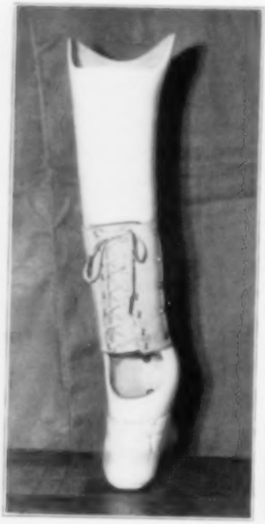


FIG. 2

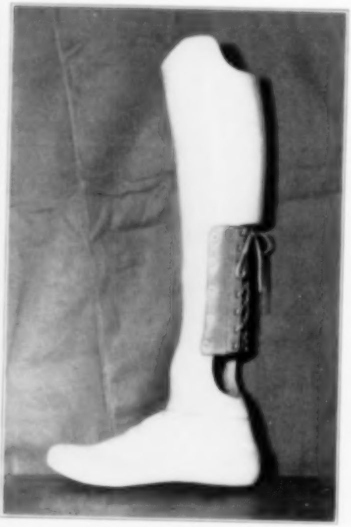


FIG. 3

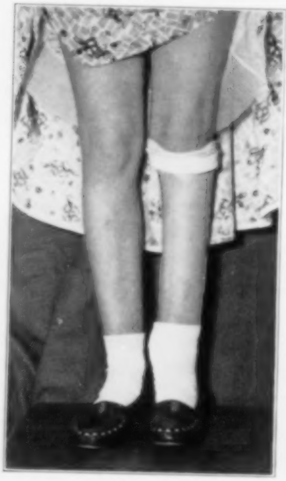


FIG. 4

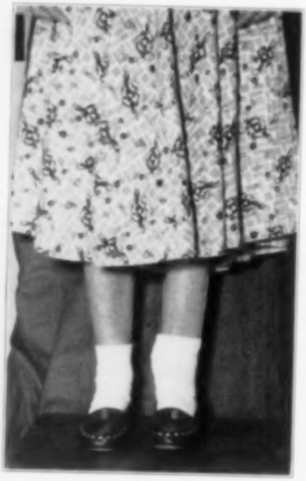


FIG. 5

Fig. 1. Photograph of the front view of the plastic Syme prosthesis without a shoe.

Fig. 2. This view illustrates the leather lacer and the cavity required to accommodate the bulbous stump.

Fig. 3. The size of the leather lacer may be seen in the side view.

Fig. 4. When the prosthesis is worn by the patient, it may be seen how successful has been the attempt to make the prosthesis follow the contour of the normal leg.

Fig. 5. The appearance of this prosthesis when the patient is fully dressed. This prosthesis has been fully accepted by the patient, and in her opinion it is much superior to any of the conventional types of prosthesis used previously.

still warm. This mold is the trial socket. It will be attached to a foot portion and after adjustments will serve as a mold for the final complete prosthesis.

A foot of the proper size is selected, giving consideration to the heel height. A set-up for length and alignment is made by setting the trial socket on the foot and temporarily securing it with steel bands from the foot to the shin by small screws. The back side of the socket is cut out sufficiently to allow the stump to be inserted. The trial socket is now fitted to the stump and adjustments are made so that it is comfortable during standing, walking, and sitting. When the socket with its attached foot is entirely comfortable, the screws are replaced with rivets and the unit is ready for the final lamination.

The foot is trimmed until it is undersize, and the outer surfaces of the foot and socket are roughened with a fine rasp or sandpaper. To obtain the most pleasing cosmetic effect possible, the spaces from foot to shin are filled with a compatible resin and filler. It is cured and sanded. The socket is now coated inside with a plastic parting agent and a second model of plaster-of-Paris is poured into it, a vented tube having been installed and all openings having been sealed.

For the second lamination, two layers of stockinet of appropriate size are pulled over the toe portion, up over the bands on the shin, and stretched tightly but not tied. Glass cloth reinforcement is wrapped about the wood of the foot and over the top of the connecting bands. Three additional layers of stockinet are pulled into place so that the first layer extends from the toes to two inches above the glass cloth which includes the top of the bands. It is stretched tightly; the second and third layers are stretched from the toes to the top of the socket and tied around the vented tube with linen thread.

The same technique and the same resins are used in this lamination as in the first one, except that the resin mixture should be 70 per cent rigid and 30 per cent flexible styrene polyester resins. The mold is oven-cured, and the top and back openings are trimmed to the original size while warm. All cut edges are smoothed and sealed so that moisture cannot penetrate the cotton fiber. Excess plasticized stockinet is cut from the foot which is sandpapered, the edges being feathered so that no ridges remain.

A leather lacer is attached over the back opening. The foot is covered in the usual manner and the prosthesis is ready for final fitting and use.

## SUMMARY

With this prosthesis it is possible to overcome the major objection to a Syme amputation in women patients and to offer them the many advantages of the weight-bearing, below-the-knee amputation of the Syme type.

## REFERENCE

1. Staff of Artificial Limbs Project, Department of Engineering, University of California. Manual of Upper Extremity Prosthetics. Edited by R. Deane Aylesworth. Los Angeles, University of California, 1952.

# A FRACTURE CART

BY RALPH T. LIDGE, M.D., CHICAGO, ILLINOIS

*From the Department of Orthopaedic Surgery, Research and Educational Hospitals, University of Illinois College of Medicine, Chicago*

A new fracture cart has been designed, used, and found satisfactory. This cart has sufficient space for all necessary equipment and is so arranged that any shortage of equipment should be immediately apparent. It is easy to move and can be brought to the patient's bedside. Its construction is simple, and its cost is not prohibitive.

## SUGGESTED LIST OF EQUIPMENT

The storage space in this cart consists of twelve top compartments, four side compartments (two on each side), and a lower compartment which runs the length of the cart. Within these compartments the supplies might be arranged in the following manner. Top compartment: (1) foot pieces; (2) hand pieces; (3) ace bandages; (4) sheet wadding; (5) moleskin for leg traction; (6) moleskin for hand traction; (7) moleskin for internal rotation, combination pads; (8) gauze bandage rollers and muslin bandage rollers; (9) tincture of benzoin, alcohol, bandage scissors, and hemostat; (10) two-by-two sponges, cotton applicators, and adhesive tape; (11) hand towels and towel clamps; and (12) tongue blades, safety-pins, and s-hooks. Side compartments: (upper, Fig. 2-A) weights of five and ten pounds; (lower, Fig. 2-A) rope; (upper, Fig. 2-B) weights of one, two, and three pounds;

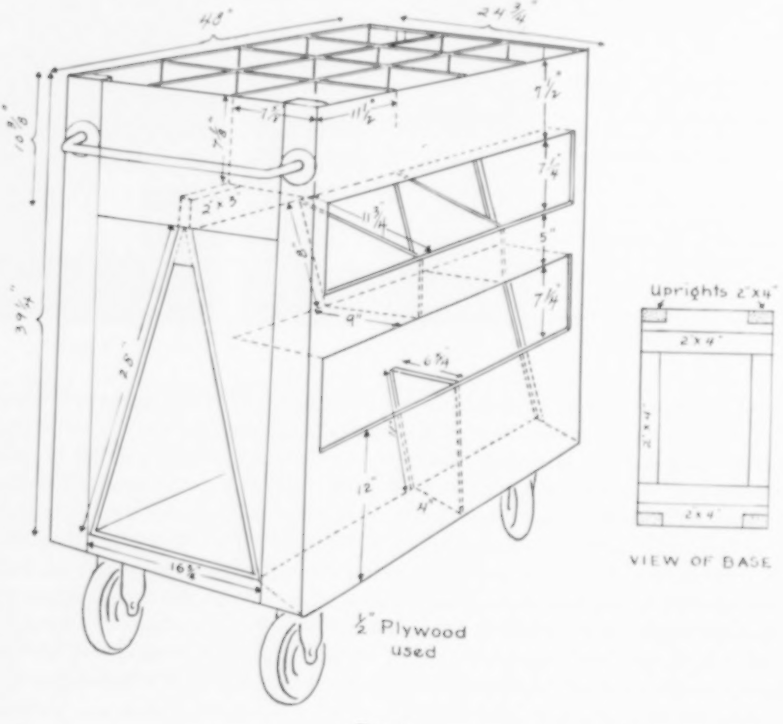


FIG. 1

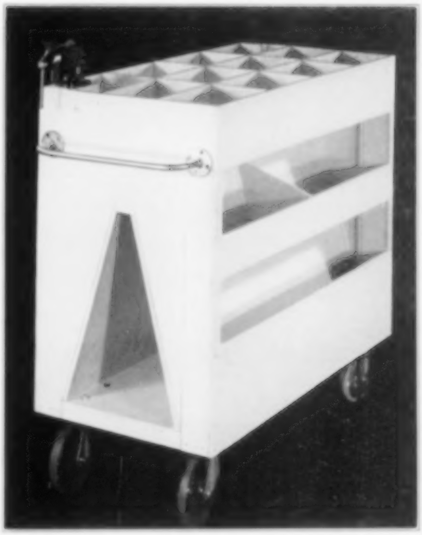


FIG. 2-A

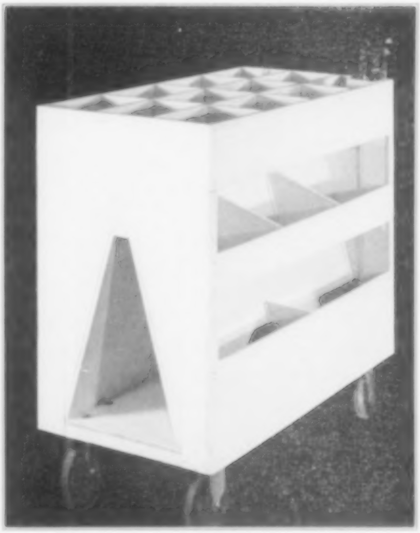


FIG. 2-B

and (lower, Fig. 2-B) pulleys and clamps. In the lower compartment which runs the length of the cart, there is room for such large devices as splints and pipes, devices that in the past have been cumbersome to move.

## MATERIALS

The wood for this cart consists of half-inch plywood, two-by-four uprights, and moulding strips. Wood screws are used because of their greater strength (except where bolts are used to fasten the wheel plates to the base). Of the two pairs of eight-inch rubber wheels, one pair is static and the other is swivel. The swivel type has a double set of bearings.

Some of the ideas for this cart were taken from the fracture cart used at Ravenswood Hospital, Chicago, Illinois.

# FUNCTIONAL WRIST SPLINT

BY ODON F. VON WERSSOWETZ, M.D., RANDOLPH N. WITT, CERTIFIED ORTHOTIST, AND ROSE ELLIOTT, B.A., O.T.R., GONZALES, TEXAS

*From the Gonzales Warm Springs Foundation, Gonzales, Texas, and the University of Texas, Medical Branch, Galveston, Texas*

The total rehabilitation of a hand affected by neuromuscular or musculoskeletal disorders requires the utilization of all available remaining muscle power for functional activities. For this purpose, it is often necessary to provide assistive supports. Such supports should reinforce the weak muscles or substitute for paralyzed muscles. They should allow optimum function of the counteracting or non-paralyzed muscles. Maximum motion of all joints should be preserved within limits of good alignment.

Weakness around the wrist is often associated with hand disabilities. In the majority of cases, the wrist extensors are more often involved than the wrist flexors. The usual procedure for correcting this condition is the immobilization of the wrist by rigid splints. Such splinting leads to progressive disuse atrophy of non-paralyzed muscles, to contractures of joint capsules, and to stiffness and limitation of mobility of joints and tendons. Several varieties of splints, such as Oppenheimer's, attempted to correct this condition, but most of them were too bulky and too hard to adjust.

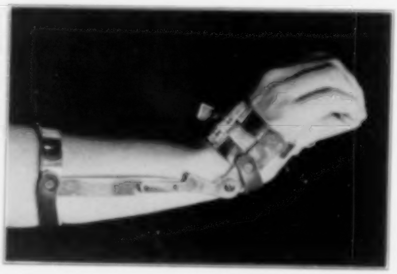


FIG. 1

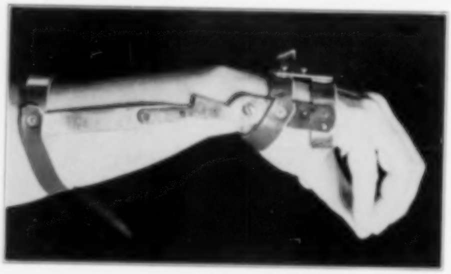


FIG. 2

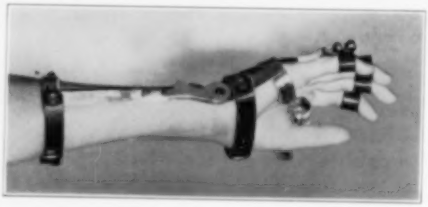


FIG. 3

A functional wrist splint with a single-action spring joint was designed at the Gonzales Warm Springs Foundation Hospital which proved satisfactory on thirty-two patients. Each spring for the brace is selected individually so that the desired tension is obtained. This tension depends on several factors, namely, on the ratio of strength between all the flexor and extensor muscles acting on the wrist joint, the weight of the splint, the usual activities to be performed, and the position of the hand and wrist during such activities. The single-action spring encased in the joint is easily adjusted individually by clinical trial. It is similar to, but smaller than, the Klenzak-Pope joint for toe-lift. A splint with such a joint permits a functional range of wrist motion, yet at rest places the wrist in the desired amount of dorsiflexion. Both dorsiflexion and palmar flexion can be controlled by placement of appropriate stops.

This dynamic and functional splint can be used alone for support of weak extensors or may be used in combination with other attachments for correction of associated disabilities.

# AN INSTRUMENT FOR USE IN EXTRACTING RUSH PINS

BY BEN FOX, M.D., MARION, ILLINOIS, AND KENNETH VAN LENTE, PH.D.,
CARBONDALE, ILLINOIS

The diagram (Fig. 1) illustrates an instrument which has been used to retrieve a Rush intramedullary pin which had dropped into the medullary canal of a radius. It has since been used to extract a Neufeld blade-plate in a hip and for removal of Rush pins from other long bones.

The Rush nail was retrieved from the medullary cavity by engaging the hook of the nail with the wire loop of the extractor through a relatively small window in the cortex of the bone.

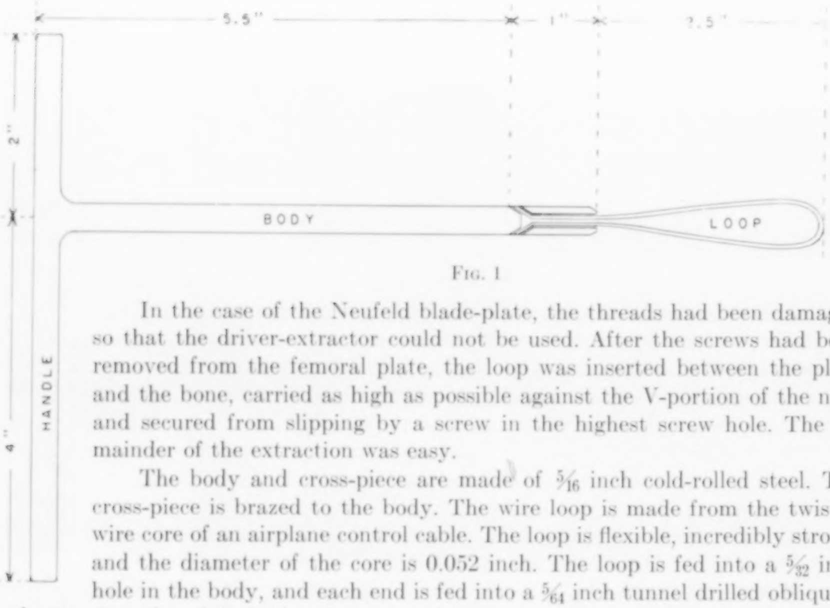


FIG. 1

In the case of the Neufeld blade-plate, the threads had been damaged so that the driver-extractor could not be used. After the screws had been removed from the femoral plate, the loop was inserted between the plate and the bone, carried as high as possible against the V-portion of the nail, and secured from slipping by a screw in the highest screw hole. The remainder of the extraction was easy.

The body and cross-piece are made of $\frac{5}{16}$ inch cold-rolled steel. The cross-piece is brazed to the body. The wire loop is made from the twisted wire core of an airplane control cable. The loop is flexible, incredibly strong, and the diameter of the core is 0.052 inch. The loop is fed into a $\frac{5}{32}$ inch hole in the body, and each end is fed into a $\frac{5}{64}$ inch tunnel drilled obliquely through opposite sides of the body to connect with the centrally located $\frac{5}{32}$ inch hole. The loop is silver-soldered to the body in the tunnels.

The strength of the apparatus was tested by hammering a twenty-penny nail into yellow pine and hooking the wire loop over the head of the nail. Hammering on the cross-piece extracted the nail but did not loosen the soldered attachments. The advantages of a collapsible and flexible loop as an extractor through small openings in the bone are obvious.

# A PRACTICAL METHOD FOR EXTRACTING IMPACTED INTRAMEDULLARY NAILS

BY WAYNE O. SOUTHWICK, M. D., AND GEORGE N. AUSTIN, M. D., BALTIMORE, MARYLAND

*From the Department of Surgery, Division of Orthopaedic Surgery, The Johns Hopkins Hospital and The Johns Hopkins School of Medicine, Baltimore*

Cherry[1] described an instrument for removing clover-leaf nails which are embedded in bone beyond the nail slot. This consisted of a screw extractor welded to a hand grip. For that purpose it seems to be quite satisfactory. The extractor is merely twisted into the nail-end, and the nail is pulled out manually.

However, when the nail is protruding the usual amount with the nail slot exposed, the screw extractor does not hold fast, if more than a moderate amount of force is needed. This is because the nail spreads and the cutting edges of the extractor slip.

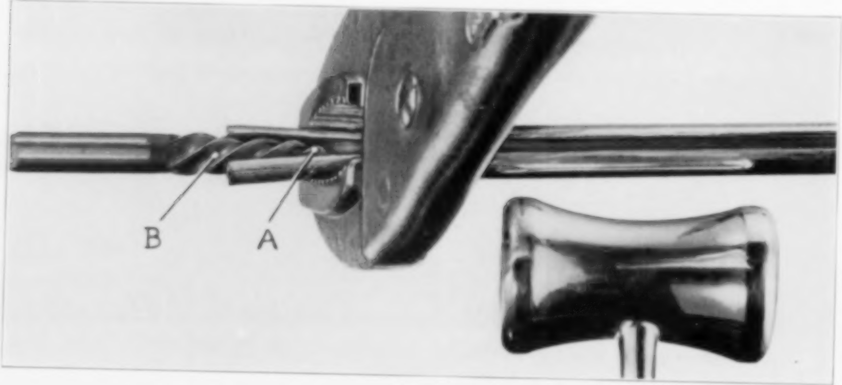


FIG. 1

If a nail is stuck, and the usual hook extractor breaks, or if the nail slot tears out, a screw extractor can still be of great help if used in the following manner:

The screw extractor (*A*) is twisted into the nail end and the nail is allowed to spread. Then a pair of ten-inch vise-grip* pliers is used to crimp the nail over the apex of the screw extractor, at the same time, locking the pliers in the illustrated position. The nose of the pliers is then struck with the mallet to remove the nail. With each blow the grasp on the nail is made more firm because the base of the extractor (*B*) is larger than the apex (*A*).

Thus far this combination has facilitated the removal of impacted and bent femoral nails where the usual hook extractors were broken.

1. CHERRY, H. L.: A Simple Efficient Extractor for Removing Clover-Leaf Intramedullary Rods. J. Bone and Joint Surg., **36-A:** 400–401, Apr. 1954.

* The "Vise-Grip" pliers are manufactured by the Peterson Manufacturing Co., Dewitt, Nebraska, and are sold in most hardware stores.

# Proceedings

## DEDICATION OF THE NEW HOSPITAL FOR SPECIAL SURGERY

OPERATED BY THE SOCIETY FOR THE RELIEF OF THE RUPTURED AND CRIPPLED

Program of Scientific Conference and Social Events held in connection with Dedication and Ninety-second Anniversary, September 29 and 30 and October 1, 1955

The Hospital for Special Surgery moved on May 25, 1955, from its old location at 321 East 42nd Street to occupy its new hospital building at 535 East 70th Street. Here, as a result of agreements negotiated with the New York Hospital-Cornell Medical Center, it becomes the Orthopaedic Service of the Center. It retains its own corporate indentity and financial management, but agrees to cooperate with the Center by furnishing all desired services in the fields of orthopaedics and rheumatic diseases in return for services in all other professional fields to be supplied by the Center. Thus it gives up all activities outside its special field of crippling diseases and disabilities but in return obtains consultative and advisory services in all other fields of medicine and public health.

The principal purpose of this move is the benefit of the Hospital's patients, but of almost equal importance is the benefit to be obtained from participation in undergraduate teaching, nurses' training, postgraduate education, and the sharing of research facilities with the Center.

FIG. 1

At the Dedication Dinner. Standing (left to right) are: Mr. Hamilton Hadley, Dr. George E. Bennett, Dr. Edward Gallie, Mrs. Samuel S. Duryee, and Mrs. Hugh Luckey. Seated (left to right) are: Mrs. T. Campbell Thompson, Sir Harry Platt, Mrs. Jean Judet, Dr. Philip D. Wilson, Dr. Walter Bauer, Mrs. Hamilton Hadley, Mr. Samuel S. Duryee, Dr. Philip S. Hench, and Lady Platt.

The dedication of the new hospital building marked the achievement of many years of discussion and planning. The matter of financing a new building became a serious obstacle particularly when, after 1948 because of inflation, the original estimate of \$3,000,000 was doubled. On the other hand, the Hospital benefited from many fortunate circumstances. First was the donation by the New York Hospital of an unexcelled building site facing on the East River between 70th and 71st Streets, second was a substantial legacy from Mrs. Mathew Wilkes, and third was the important increment of value of the property, owned by the Society for the Relief of the Ruptured and Crippled, between East 42nd and 43rd Streets at Second Avenue, and occupied in part by its hospital building. This increase in value occurred from improvements resulting from the demolition of the Second Avenue Elevated structure and from the development of the United Nations buildings. It was thus possible to negotiate the sale of the hospital property for a sum which left a deficit of about \$1,500,000 to be raised in order to complete the new building. With confidence in support from the public and with the risk of impairment of capital, the Board of Managers authorized the beginning of construction. Their confidence was not misplaced and the necessary funds were raised before the building was completed.

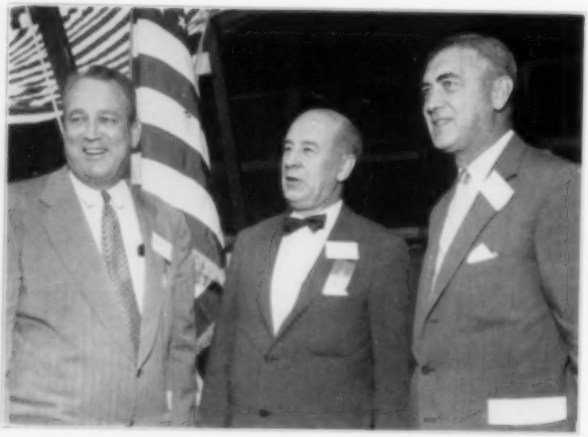


FIG. 2

On the Speakers' Platform at the Dedication ceremony are (left to right): Dr. T. Campbell Thompson, Surgeon-in-Chief; Mr. Samuel S. Duryee, President, Board of Managers; and Dr. Gordon Petrie, President, Alumni Association of the Hospital for Special Surgery.

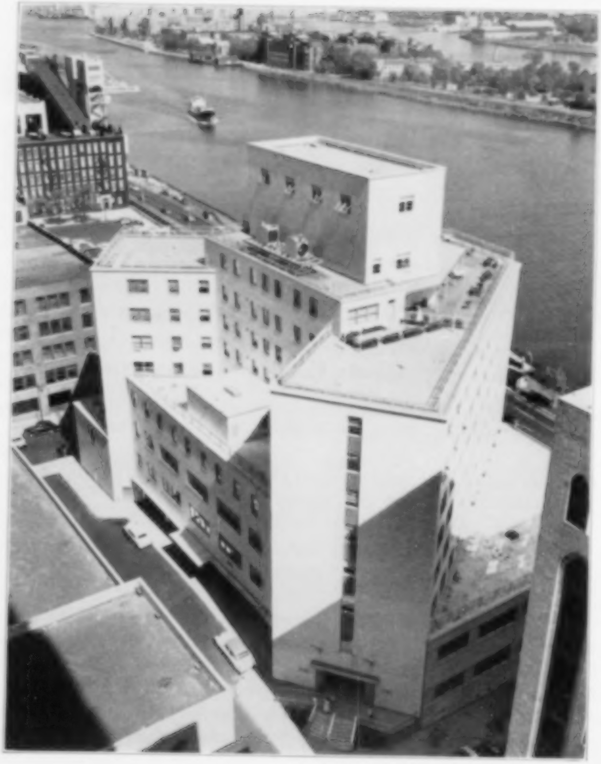


FIG. 3

View of the new Hospital for Special Surgery looking toward the East River from the fifteenth floor of the New York Hospital.

The new building, planned by Rogers and Butler, Architects, and built by Vermilya-Brown is of unique design. It is an eight-story structure with basement and sub-basement and is linked with the New York Hospital by tunnel. Its lower two floors and basements are four-square and house kitchen, lobby, out-patient clinics, Departments of Social Service, Radiology, Physical Medicine, and ancillary services. Above this, the building continues upward in the form of an A with the apex towards the East River. This permits practically all of the patients' rooms to face the river, with the utility and the service rooms on the interior. The decorating and window and door treatment are modern with the use of much color, so that the effect is much more that of a hotel than of a hospital. Total bed capacity is 170 but this can be expanded to 200 by the completion of an unfinished wing.

The old Hospital for the Ruptured and Crippled was founded in 1863 by Dr. James Knight with the help of a group of charitably disposed persons. It was the first orthopaedic institution in the United States and was placed in Doctor Knight's home on Second Avenue. The original records are still preserved and reveal the careful examination and treatment given there. The increasing demand of patients led to the construction of a new and especially designed hospital accommodating 200 persons on 42nd Street at Lexington Avenue. Under Dr. Virgil Gibney, who held the position of Surgeon-in-Chief from 1887 to 1924, the orthopaedic and hernia services developed and benefited from the advance of operative surgical technique and the introduction of roentgenography. In 1912, benefiting from Commodore Vanderbilt's desire to build the Grand Central Terminal for the New York Central Railway, the Hospital moved to a new hospital plant which had been constructed on 42nd Street about two and a half blocks east of its old site, which is now occupied by the Commodore Hotel.

In the course of its history, extending over 92 years, the Hospital has undergone an evolution from separatism and isolationism, which benefited the pioneering spirit, to affiliation and cooperation with the whole body of medicine. This will be of help to our patients and to the teaching of both undergraduate and postgraduate students. In spite of all these changes, however, we believe that the spirits of Knight, Gibney, Coley, and Pool would be pleased to observe the same dedication of the doctors to the service of their patients, the same devotion to teaching, and the same insistence on truth and accuracy of observation on the part of resident surgeons which they taught many years ago.

The Dedication Exercises and Scientific Conference were planned to memorialize the contributions of the Founders and Leaders of the Hospital for Special Surgery, to introduce new approaches to our clinical problems, and to stimulate scientific curiosity on the part of our medical guests and Staff Members.

## PROGRAM FOR DEDICATION CEREMONY

Thursday, September 29, 1955

Four-thirty P.M.

Samuel S. Duryee, Esq., President, New York Society for the Relief of the Ruptured and Crippled, *Presiding*.
T. Campbell Thompson, M.D., Surgeon-in-Chief, The Hospital for Special Surgery;
Philip D. Wilson, M.D., Surgeon-in-Chief, *Emeritus*, and Director of Education and Research, The Hospital for Special Surgery;
Hamilton Hadley, Esq., President, The Society of the New York Hospital;
Dr. Deane W. Malott, President, Cornell University;
Dr. Detley Bronk, President, Rockefeller Institute for Medical Research;
Miss Jane Pickens;
The Right Reverend Donald B. Aldrich, Bishop, Protestant Episcopal Church.

During this program, the President of the Hospital announced the receipt of legacies from the estates of William R. Coe, of Alfred Caspary, and of Helen Bicknell, totalling approximately $6,000,000. These sums were left entirely for education and research in the new Hospital. He also announced plans for the construction of the Alfred Caspary Research Department of the Hospital for Special Surgery. This building is to rise on a lot belonging to the Hospital, directly to the North, across 71st Street, and will be joined by a bridge to the hospital building.

## SCIENTIFIC PROGRAM

Thursday, September 29, 1955

*The Rehabilitation of the Crippled Child*

A.M. Moderator: Dr. Alfred R. Shands, Jr., Medical Director, Alfred I. duPont Institute of the Nemours Foundation, Wilmington, Delaware.

1. *Pediatric Rehabilitation. A Total Program.* DR. S. Z. LEVINE [1] emphasized the importance of thinking of the whole child in planning orthopaedic rehabilitation. A team approach, including the services of a pediatrician, physiatrist, psychiatrist, and social service workers, as well as an orthopaedist, was recommended.

2. *The Goals of Good Nursing Service.* MARY ELLEN MANLEY [2] emphasized the point that before obtaining the goals of good nursing, it is first necessary to supply enough nurses. She gave figures on the number of nurses available in comparison with the demand and spoke of the steps that are being taken to ease this shortage.

3. *The Social Needs of the Crippled Child.* ELIZABETH P. RICE [3] stressed the importance of understanding the goal obtainable in each case by integration of services working to that end.

4. *Where Next?* DR. LEONA BAUMGARTNER [4] expressed appreciation for the services the Hospital for Special Surgery had rendered in the past. She emphasized the changes that have taken place in the type of patients and the diseases or conditions treated. It is necessary for a hospital to be able to keep up with the changing trends in medical practice and to foresee future developments as early as possible.

5. *Orthopaedic Service for the Crippled Child.* DR. ALFRED R. SHANDS, JR., gave an excellent résumé of the various requirements for good orthopaedic service for the crippled child. He attempted to predict the future demands and how best to give the services that would be required.

P.M. Moderator: Dr. Howard Rusk, Chairman, Department of Physical Medicine and Rehabilitation, New York University-Bellevue Medical Center, New York, N. Y.

---

[1] Pediatrician-in-Chief, The New York Hospital Cornell Medical Center, New York, N. Y.
[2] Secretary, State Board of Nurse Examiners, State Education Department, Albany, New York.
[3] Associate Professor, Harvard University School of Public Health, Boston, Massachusetts.
[4] Commissioner of Health, The City of New York.

6. *Emotional Problems of the Crippled Child.* DR. LESLIE HOHMAN[5] presented the emotional problems of the crippled child simply from two standards: first, that the crippled child has all the emotional problems of a normal child and, second, that on top of this, he experiences the problems growing from the fact of his crippling.

7. *The Future of Poliomyelitis.* DR. HART E. VAN RIPER[6] gave a résumé of the results already attained from immunization of children with poliomyelitis vaccine. With the exception of a few bad results following the use of certain lots of vaccine in the early part of the immunization program, there have been no reports of unusual reactions. The cause of the early complications was soon discovered and remedied. Paralytic poliomyelitis developed in a certain number of vaccinated children, but these children had not received the necessary booster inoculation. He did not think that we could look forward to the complete elimination of poliomyelitis, but he did think that the number of paralytic cases would be greatly reduced.

8. *The Problem of Cerebral Palsy Today.* DR. GLIDDEN L. BROOKS[7] reviewed the various problems of cerebral palsy encountered in all communities. He reported a vast increase of facilities for the care of affected children and referred to the considerable progress that had been made, although much still remains to be done.

9. *"A Crippled Child Shall Lead Them. . . ."* DR. HOWARD RUSK showed how rehabilitation services for the crippled child were first developed. It was largely from the experience gained and the results obtained in these cases that a program was formed to meet the needs of the military services during the war. The experience with casualties led to the development of new techniques and better understanding of what was required to provide for the total needs of the disabled, making possible the expansion of civilian rehabilitation facilities and services which are proving so successful today.

10. *Rehabilitation of the Physically Handicapped Child.* SIR HARRY PLATT[8] described the development of orthopaedic and rehabilitation services for crippled children in Great Britain, and the large part that had been played by Sir Robert Jones and Dame Agnes Hunt in organizing these services on a broad scale. Small clinics in the country, where diagnostic and after-care services are given, are grouped about the various orthopaedic centers. These services proved so satisfactory that they have been retained and developed even further since the passage of the Health Act, which gives governmental support to them.

Friday, September 30, 1955

*Clinical Problems of Orthopaedic Surgery*

A.M. Moderator: Dr. Edward Gallie, Professor of Surgery, *Emeritus*, University of Toronto, Toronto, Ontario, Canada.

This group of clinical papers were beautifully presented with lantern slides and motion pictures. Dr. Gallie, the Moderator, who had been a house officer at the Hospital in 1905–1906, added some pertinent comments.

1. *My Experience with the Capsular Arthroplasty for the Dislocated Hip.* DR. PAUL C. COLONNA[9] gave a complete report of the operation for congenital dislocation of the hip that he had developed more than twenty years before, when he was on the Staff of the old Hospital for the Ruptured and Crippled on 42nd Street.

2. *The Results of Closed Reduction in Congenital Dislocation of the Hip.* SIR HARRY PLATT[8] gave an excellent picture of how this problem has been handled in his clinic in Manchester, England.

3. *Surgical Treatment of the Volkmann's Ischaemic Contracture.* DR. OSCAR SCAGLIETTI[10] presented a motion picture showing how the deformities associated with Volkmann's contracture can be corrected by well planned extensive surgery. Both the photographic and surgical techniques were admirable.

4. *Fundamental Principles and Treatment of Scoliosis.* DR. ALBERT C. SCHMIDT[11] presented the subject of scoliosis and its treatment in a clear and concise manner which helped greatly to clarify this all too complicated subject.

5. *Fractures in Children.* DR. WALTER P. BLOUNT[12] presented with the help of some excellent cartoons the highlights of his new book *Fractures in Children*.

---

[5] Professor of Neuropsychiatry, Duke University School of Medicine, Durham, North Carolina.

[6] Medical Director, National Foundation for Infantile Paralysis, New York, N. Y.

[7] Medical Director, United Cerebral Palsy, New York, N. Y.

[8] President, Royal College of Surgeons of England.

[9] Professor of Orthopaedic Surgery, University of Pennsylvania Medical School, Philadelphia, Pennsylvania.

[10] Surgical Director, Istituto Ortopedico Toscano, Florence, Italy.

[11] Chief of Surgery, Milwaukee Children's Hospital, Milwaukee, Wisconsin.

[12] Chairman, Orthopaedic Department, Milwaukee Children's Hospital, Milwaukee, Wisconsin.

6. *The Direct Surgical Attack on Focal Lesions in Tuberculosis of the Bones.* Dr. Jean Judet[13] showed that with the new antibiotics the surgical treatment of tuberculosis of the bones may be undertaken earlier and with little danger of complications and that the result is often far superior to that from an arthrodesis which has usually been considered to give the best result obtainable.

P.M. Moderator: Dr. George E. Bennett, Professor, *Emeritus*, Orthopaedic Surgery, Johns Hopkins University, Baltimore, Maryland.

7. *Tissue Culture Studies of Bone Growth and Metabolism.* Dr. Robert D. Ray[14] with Joan Schmidt and Duane LaViolette discussed the problem of whether or not frozen bone remains viable. He showed interesting sections of bone which lived apparently at −78 degrees centigrade in 15 per cent glycerol and blood-serum media. He demonstrated that rapid freezing apparently killed the bone. This technique, however, still remains a laboratory problem.

8. *The Relations of the Apatite Inorganic Crystals to the Organic Matrix of Bone and Epiphyseal Cartilage.* Dr. Robert A. Robinson[15] discussed the relation between the organic matrix and the inorganic crystals of bone with electron microscope studies and historadiographs. The pattern of crystals and their relation to collagen was beautifully depicted.

9. *The Physiological Turnover of the Mineral of Bone.* Dr. Franklin C. McLean[16] discussed the recent concepts of the mineral turnover in bone. In a very thorough review, he stated that within two and one-half minutes, injected calcium-45 has already been distributed. He also stated that sodium in the blood can exchange for calcium and that such ionic change can overshadow accretion of bone. The interesting problem of the homeostatic regulation of calcium by means of a "feedback" regulator was also thoroughly presented.

10. *Regulation of Blood Calcium.* Dr. D. Harold Copp[17], in a further paper on the relation of calcium to soft tissues, stated that parathyroid glands apparently act to produce dissolution from the crystals, perhaps by kelating agents. He also demonstrated the various chemical regulations which act to maintain the remarkably constant mineral levels in the blood.

11. *Mechanism of Nutrition in Bone and How It Affects Its Growth, Repair, and Transplantation.* Dr. Arthur W. Ham[18], by means of slides, demonstrated the mechanism of nutrition of bone, pointing out that only 0.5 millimeter distance away from a blood supply is all that can be permitted if bone is to survive. Resorption and accretion of bone were shown to be direct functions of the nutritional mechanism.

Saturday, October 1, 1955

*Studies of Connective Tissue and Rheumatic Diseases*
(Program Organized by Division of Rheumatic Diseases)
Moderator: Dr. Walter Bauer, Chief of Medical Services, Massachusetts General Hospital, and Professor of Clinical Medicine, Harvard Medical School, Boston, Massachusetts.

1. *Some Structural and Chemical Properties of Connective Tissue.* Dr. Jerome Gross[19] pointed out that, with the use of modern laboratory tools, particularly the electron microscope, the structure of connective tissue has become better understood. The nature of the fibrils of fibrous connective tissue are similar in many species of animals. Connective-tissue fibrils can be caused to disintegrate by certain chemical treatment and to reform into normal fibrils again.

2. *Biochemical and Histological Aspects of in vivo Cultivated Connective Tissue.* Dr. Robert Boucek[20] studied the manner in which fibrous connective tissue could be altered by a unique method of *in vivo* cultures grown on sponges placed in subcutaneous tissues of living animals. The sponges were subsequently removed and the fibrous tissue grown into them was studied by chemical and histological means. In patients with scleroderma, a new hormone, relaxin, was found to have profound benefits on the sclerosis, as well as on the skin ulcers in the diseased hands and feet.

3. *Non-Articular Rheumatism.* Dr. H. H. Kellgren[21] reported several distinct clinical syndromes of extra-articular rheumatic disease and many symptoms of poorly defined nature with non-articular charac-

---

[13] No. 3, square Desaix, Paris 15, France.
[14] Associate Professor of Surgery, University of Washington Medical School, Seattle, Washington.
[15] Professor of Orthopaedic Surgery, Johns Hopkins University, Baltimore, Maryland.
[16] Professor, *Emeritus*, Department of Physiology, University of Chicago, Chicago, Illinois.
[17] Professor of Physiology, University of British Columbia, Vancouver, British Columbia, Canada.
[18] Professor of Anatomy, Faculty of Medicine, University of Toronto, Toronto, Ontario, Canada.
[19] Associate in Medicine, Harvard Medical School, Boston, Massachusetts.
[20] Associate Professor of Medicine, University of Miami School of Medicine, Miami, Florida.
[21] Director, Rheumatism Research Centre, University of Manchester, Manchester, England.

teristics. The incidence of this type of rheumatism was found to be quite high in the workers in the region of England surveyed. The importance of recognizing these forms of non-articular rheumatism was emphasized.

4. *Study of Metabolic Defects in Gout.* Dr. DeWitt Stetten [22] reported on intensive studies in which radioactive isotopes, particularly labeled nitrogen, in glycine and other simple forms, were used and yielded valuable information elucidating the metabolism of purines and other proteins in the formation of uric acid. Gouty individuals were found to have a much larger pool of uric acid in metabolic activity than did nongouty individuals. Much of the intermediary metabolism was clarified by these studies.

5. *Newer Knowledge of Corticosteroids.* Dr. Ralph I. Dorfmann [23] gave a complete review of the synthesis of corticosteroids and their metabolism in relation to various diseases. The value of intensive chemical research leading to the formation of improved corticosteroids for experimental and clinical use was emphasized.

6. *Corticosteroids in the Management of Rheumatic Diseases.* Dr. Philip S. Hench [24] presented an historical review of the use of corticosteroids and corticotropin in the treatment of rheumatic diseases. The improvements in the production of corticosteroids having less undesirable side effects have led to the most recent synthesized preparations, prednisone and prednisolone, which are now the preferred therapeutic agents. The benefits, hazards, and limitations of their use were discussed and the hope was expressed that improvements would continue to make these more dependable and less troublesome therapeutic agents.

---

[22] Associate Director in Charge of Research, National Institute of Health, Bethesda, Maryland.

[23] Associate Director of Laboratories, Worcester Foundation for Experimental Biology, Shrewsbury, Massachusetts.

[24] Professor of Medicine, Mayo Foundation, and Graduate School, University of Minnesota, Rochester, Minnesota.

## NEW JERSEY ORTHOPAEDIC SOCIETY

The Fall Meeting of the New Jersey Orthopaedic Society was held on October 15, 1955, at Presbyterian Hospital, Newark, New Jersey. The meeting was conducted by Dr. John J. Flanagan,[1] President of the Society.

Abstracts of the papers are as follows:

*Hip Pain Associated with Irradiation of Female Pelvic Organs.* Dr. Vincent A. Scudese [2] stated that when hip pain develops following irradiation for pelvic malignancy, it is most often due to femoral-neck fracture. Early fracture may develop with almost negligible trauma. It should be recognized and treated early; union will take place in most instances.

Dr. Orlando G. Caprio [3] stated, in discussion, that the fracture occurs in less than 2 per cent of all cases irradiated for malignancy. He demonstrated that the usual ports used in pelvic irradiation expose the hip joint to irradiation also.

*Recurrent Dislocation of the Patella.* Dr. Robert Finnessey [4] felt that this was a relatively rare anomaly. He reported that twelve patients visited the New Jersey Orthopaedic Hospital with this condition in over twenty-four thousand clinic visits for all other conditions. The dislocation was due to one or more of the following causes: genu valgum, agenesis of the patella, aplasia of the lateral femoral condyle, and inadequacy of the vastus medialis. Treatment by distomedial displacement of the patellar ligament resulted in only two satisfactory results. A high incidence of degenerative changes in the patella is found with tangential x-rays. The degenerative changes are more disabling than the recurring dislocation.

---

[1] 517 Centre Street, South Orange, New Jersey.

[2] 440 Parker Street, Newark, New Jersey.

[3] 428 Third Avenue, Newark, New Jersey.

[4] New Jersey Orthopaedic Hospital, Orange, New Jersey.

*Cartilage-Mold Hip Arthroplasty.* **Dr. Paul Strassburger** [5] reviewed the details in technique of producing a cartilage hip mold. Diced rib cartilage is placed in a mold and is buried in the patient's abdominal wall for six months. An autogenous, living cap of cartilage and connective tissue is thus produced. An eleven-year-old girl was presented in whom this arthroplasty had been performed for an inflammatory arthritis. The longest follow-up in any case is three years.

Dr. John Flanagan [1] stated that experimental work is still going on. The chief disadvantage of the procedure is the necessity for two operations and the wait of six months between operations.

*Complications of Hip Prostheses.* **Dr. Arthur D. Devlin** [6] reported that the complications he had had in using the F. R. Thompson prosthesis were dislocation, infection, pain, and fracture of the femur. Due to the high incidence of complications in his entire series, he concluded that the use of the prosthesis is chiefly indicated in traumatic cases.

**Dr. William Kruger** [7] showed a Judet acrylic prosthesis that had broken two years after insertion.

*Hemiplegic Gaits.* **Dr. Earl F. Hoerner** [8] demonstrated various hemiplegic gaits which he classified into seven types. Many are due to compensatory actions following equinovarus deformity of the foot. He felt that making a monarticular muscle out of a biarticular muscle was desirable in improving function; he stressed training and bracing in treatment. Surgery was advised for true contractures and not for muscle transplantation.

*Unusual Malignant Conditions Seen in Orthopaedic Practice.* **Dr. Jarvis M. Smith** [9] and **Dr. Eugene A. White** [10] presented two cases of metastases to the superior pubic ramus in which identical symptoms, clinical findings, and roentgenographic appearances had been recorded. One was shown to be a case of malignant melanoma, the other a retroperitoneal neuroblastoma or the so-called sympathicoblastoma.

**Dr. Henry Jaffe** [11] spoke of the difficulties encountered in making diagnoses in metastatic lesions even from biopsy material. There may be a different appearance in the same tumor in a given patient between the primary and metastatic lesion because the tissue pattern may not be reproduced.

*Engelmann's Disease with Fracture.* **Dr. Albert Willner** [12] presented a thirty-five-year-old female patient with this unusual hereditary diaphyseal osteosclerosis and discussed the problems in treating, first, one femoral fracture, and, then, the other. A medullary canal was established and intramedullary fixation was done. A brother with a similar condition was discovered. This is the fourth case reported in the literature. The characteristics, according to Engelmann, are symmetrical fusiform enlargement with sclerosis of shafts of major bones associated usually with changes in the skull.

*A Review of Surgical Treatment of Solitary Bone Cysts at New Jersey Orthopaedic Hospital.* **Dr. John J. Reilly** [13] analyzed the results in seventeen patients with nineteen operations consisting basically in curettage of the cyst and replacement with bone chips, the majority coming from the bone bank. Chemical cauterization was used in eight cases. A recurrence or persistence rate of 58.8 per cent was noted by roentgenogram, although over one-half of these showed only a small defect remaining. Practically speaking the results were good in general.

At the business meeting, the following officers were elected for 1956: Dr. William Kruger [7], President; Dr. Bernard M. Halbstein [14], President-elect; Dr. Arthur S. Thurm [15], Secretary; Dr. Harold T. Hansen [16], Treasurer.

[5] 330 Washington Avenue, Belleville 9, New Jersey.
[6] 502 Prospect Street, Maplewood, New Jersey.
[7] 31 Lincoln Park, Newark, New Jersey.
[8] Kessler Institute for Rehabilitation, West Orange, New Jersey.
[9] 198 Valley Road, Montclair, New Jersey.
[10] 198 Valley Road, Montclair, New Jersey.
[11] Hospital for Joint Diseases, New York, N. Y.
[12] 115 Ridge Road, North Arlington, New Jersey.
[13] 222 Elizabeth Avenue, Elizabeth, New Jersey.
[14] 263 Bath Avenue, Long Branch, New Jersey.
[15] 533 West State Street, Trenton 8, New Jersey.
[16] 153 Irvington Avenue, South Orange, New Jersey.

# THE AMERICAN ORTHOPAEDIC ASSOCIATION

## Annual Meeting 1955: The Scientific Sessions

*Functional Arm Bracing.* Dr. Edwin R. Schottstaedt [1] and Mr. George Robinson [2] presented the principles which they had found to underlie the functional bracing of an upper extremity handicapped by poliomyelitis. The authors had carefully analyzed the significant functions of the hand, wrist, elbow, and shoulder and had utilized light and relatively easily constructed auxiliary braces to activate the limb by means of the shoulder, ankle, and hip motors. The braces used had included the handy hook, the spring motor for pronation and supination, the shoulder-rotation unit, the multiple-locking elbow, and the reciprocator. By the use of these braces, dramatic and effective functional improvements had been brought about in arms which had formerly seemed hopeless. The illustrations presented with this article added greatly to its clarity.

*Upper-Extremity Prostheses in Juvenile Amputees.* Dr. Claude N. Lambert [3] reported a series of sixty juvenile amputees upon whom upper-extremity prostheses had been applied. In some of these patients the arm had been amputated after trauma, and in some the absence of the arm was congenital. A ten-minute motion picture and a number of lantern slides illustrated the great progress that has been made in the use of upper-extremity prostheses.

The level of the amputation in the sixty patients was as follows: (1) In ten males and six females, the amputations were above the elbow, nine being congenital and seven acquired. (2) In twenty-six males and twenty females the amputations were below the elbow, thirty-six being congenital and ten acquired. (3) In one male disarticulation had been performed at the elbow. (4) In two males and two females, disarticulation had been performed at the shoulder.

The author particularly emphasized the point that the upper-extremity prosthesis can and should be applied to very young children. When the program was first begun, the age of five was arbitrarily selected as the youngest age at which it was practical to apply a prosthesis. It soon became apparent, however, that the younger child adapts himself to the prosthesis much more readily than does the older child, and as a result of this observation, the age at which the prosthesis is applied today is considerably lower than the age at which it used to be applied. The youngest child in the author's group was twenty-two months of age.

With three exceptions the prostheses used in the author's series had the voluntary-opening hook. The hands designed by the Army Prosthetic Research Laboratory had not been used primarily because they are not made in a small size and because their cost is almost prohibitive. The training essential for the proper use of the upper-extremity prosthesis is not limited to the child alone, and the author emphasized the importance of the parents' attitude. One must read the entire article and see the motion picture and the lantern slides to appreciate how great an advancement has been made in this field.

*The Water Content of Bone and Its Relationship to the Organic and Mineral Components of Bone Matrix.* Dr. Robert A. Robinson [4] and Dr. Stuart R. Elliott [5] pointed out that knowledge of the water content of bone and of the relationship of this content to the organic and inorganic components of bone is important not only in connection with preserving bone for grafting but also in connection with understanding better the processes of ionic exchange which occur within bone.

Since each of the components of bone may vary in volume at any one time, since the density of each of the components is different, and since the density of the osteoid changes with calcification, component determinations must be recorded as percentages of volume rather than as percentages of weight, if these determinations are to be correlated with newer biophysical data.

In the authors' study the determinations had been made on samples of mid-shaft cortex of canine tibiae. These samples had been stripped of soft parts and had been fully hydrated by overnight immersion in distilled water at four degrees centigrade. The hydrated samples had been weighed when suspended in water by a fine wire and had then been weighed again in the air after the surface dampness had been removed by a blotter. The difference between the two weights, corrected to allow for the weight of the suspension wire, had given the weight of the water displaced and hence the volume of the sample; from this the density of the hydrated sample had been obtained.

Volume and weight studies had also been made of bone ashed at 600 to 650 degrees centigrade, of samples of bone decalcified in trisodium versenate solution, and of samples of bone subjected to ether-alcohol extraction. Calcium and nitrogen determinations had been made on ashed bone and on undecalcified and decalcified samples of hydrated bone, respectively.

---

[1] Franklin Hospital, San Francisco 14, California.

[2] San Francisco, California.

[3] 103 South Michigan Avenue, Chicago 3, Illinois.

[4] The Johns Hopkins Hospital, Baltimore 5, Maryland.

[5] Johns Hopkins University Medical School, Baltimore, Maryland.

The bone samples had become fully hydrated shortly after immersion in a bath of distilled water of pH 6.9. The weight of fully hydrated bone of a density of 1.8 or over remains constant for many days at 4.0 degrees centigrade. Hydrated bone of a density of below 1.7 begins to lose weight after about twenty-four hours. Reproducible weight and volume measurements can be made on fully hydrated fresh bone within twenty-four hours after excision.

The amounts of water which may be removed from bone by desiccation *in vacuo* at room temperature, by freeze drying, by heating at 50 degrees centigrade, and by heating at 100 to 105 degrees centigrade are not all the same. When water had been removed by heating at 50 degrees centigrade, by freeze drying, and by desiccation *in vacuo,* an equal quantity of water had been reabsorbed by samples of prehydrated bone having a density of 1.8 or above. The bone of high density which had been repeatedly dried at a temperature of over 100 degrees centigrade had become friable, the organic matrix undoubtedly becoming altered in some way by the repeated heating at such a high temperature. Hydrated bone with a density of 1.7 or below could not be fully rehydrated after dehydration regardless of the method used to remove the water. In high-density bone heating at 100 degrees centigrade, if not repeated too often, results in a water loss which is largely replaceable by immersion of the bone in water; heating at between 100 and 300 degrees causes an irreplaceable weight loss; heating at between 300 and 500 degrees leaves only the bone crystals, which can hold one-third of their weight in water; and heating at over 500 degrees causes crystal enlargement and loss of water-holding capacity.

In sections of hydrated bone of uniform thickness and low density (1.42), the water-holding marrow-vascular-osteocyte spaces occupy about 60 per cent and the matrix about 40 per cent of the total area, as shown by calibrated enlargements of photomicrographs. In bone of a density of 1.85, the marrow-vascular-osteocyte area comprises about 35 per cent and the matrix about 65 per cent of the total area; and in bone of a density of 2.05, the ratio of the marrow-vascular-osteocyte spaces to the matrix is about 30: 70. Since the thickness of the sections is constant, it is suggested that these percentages also represent the ratios of the volumes of the components to the total volumes of the hydrated bone samples of the respective densities. The calculations of volume correspond rather closely to the volumes of water removed by dehydration from the samples of hydrated bone having densities of 1.42, 1.85, and 2.05. Since the contents of the marrow-vascular-osteocyte spaces are considerably hydrated, it is concluded that the bulk of the water in any bone sample is in these spaces rather than in the calcified osteoid.

One hundred and forty-four samples of tibial cortex from normal dogs had provided the data from which the graphs recording the results of the study had been calculated. The volume of each major component of the samples of hydrated bone of each density had been plotted against the weight per cent, and the weights of each component at each density had been plotted against the volume per cent. The trend line in the graphs had been obtained by the method of least squares.

The weights and volumes of the whole specimens when hydrated and dry and the weights and volumes of the water, ash, "$CO_2$ space", and organic components of the specimens when hydrated and dry had been calculated. There had been an indication of correlation between the specific gravity of the whole sample in a dry state and the specific gravity of the whole sample in a hydrated state. Under the laboratory methods used in this investigation, the specific-gravity measurements had been practically equivalent to the density measurements.

The density of a hydrated sample can be related to its porosity and is determined by the ratio between the volume of the marrow-vascular-osteocyte space and the volume of the actually calcified osteoid, the water residing largely in the marrow-vascular-osteocyte spaces and not in the calcified osteoid. Since the cortices of the long bones in puppies are more porous than are those of the long bones in adult dogs, the density of hydrated bone from puppies is less than that of hydrated bone from adult dogs. In this study densities of from 1.35 to 2.05 had been found, the densities of bone from adult dogs being 1.8 to 2.05 and the densities of bone from puppies being under 1.8. The systematic variation of the data had been greater for hydrated puppy bone than for hydrated adult-dog bone. The average data for both puppy and adult-dog bone had followed the same patterns, however.

The density of a dry cortical bone sample appears to be related to the completeness with which its extracellular osteoid matrix has been calcified. Since the over-all calcification of the osteoid in dry bone from older dogs is higher than that of the osteoid in dry bone from puppies, the density of dry adult-dog bone is higher than the density of dry puppy-dog bone. The average density of the dry samples of both puppy and adult dogs had been found to be 2.3. Dry samples of human cortical bone have a slightly lower and dry samples of rabbit bone a slightly higher average density than do those of dog bone.

A comparison of the densities of all the bone samples when dry with their densities when hydrated had revealed that there is a direct relationship between the density of bone when dry and its density when wet. In both the dry and hydrated states, adult-dog bone has a higher density than does puppy bone.

In any sample of bone, there are at least two water-holding compartments; these are the marrow-vascular-osteocyte compartment and the space occupied by the organic element of the bone matrix. Estimates of the water content of the latter had been possible through use of the formula:

$$K = \frac{(\text{Vol. \%* of dry ash}) + (\text{Vol. \% ``}CO_2\text{ Space''}) + (\text{Vol. \% osteoid matrix water})}{(\text{Vol. \% dry organic})}$$

The constant K had been calculated to be 1.6 for dog bone.

There may be more water or more apatite crystals per unit volume in extracellular osteoid as it is formed, due to variable mineralization. It is suggested that where the volume per cent of water in the osteoid is minimal, there is a reduction in the ionic exchange between the surfaces of the inorganic crystals in the osteoid and any environment external to the calcified osteoid.

The relation between the density of a hydrated bone as a measure of porosity and the density of a dry bone as a measure of the completeness of calcification of osteoid is significant.

The ratios of calcium to nitrogen and of ash to the organic component, determined by bone analyses, are not of themselves a measure of the calcification of the osteoid, for these ratios must be considered in relation to the porosity of the specimen, that is, to the density of the hydrated specimen.

* Volume per cent of original hydrated volume of the sample.

*Pes Cavus. Selective Plantar Muscle Denervation.* DR. GEORGE J. GARCEAU[6] and DR. MALCOLM BRAHMS[7] presented a preliminary review of their experience with selective plantar-muscle denervation in the treatment of pes-cavus and cavo-adductus deformities. The first patient treated by this method had been a child with a cavus deformity due to poliomyelitis. In this child all the muscles below the knee with the exception of the short toe flexors and the abductor hallucis had been completely paralyzed. By the performance of selective neurectomy of the medial and lateral plantar nerves, marked improvement in the contour of the child's foot had been obtained. As a result of this experience the authors had been encouraged to perform the operation upon patients with congenital pes cavus, congenital talipes equinovarus, arthrogryposis, pes cavus following poliomyelitis, and pes cavus of undetermined origin.

The authors concluded that certain muscles, acting under conditions of imbalance, are the principal deforming factors. These muscles are the abductor hallucis, flexor digitorum brevis, flexor hallucis brevis, and the quadratus plantae.

The anatomy of the short muscles of the plantar aspect of the foot was discussed in this paper, and the surgical approach to the denervation of the medial and lateral plantar nerves was described. The operation had been performed on forty-seven feet, the youngest patient operated upon being four and one-half years of age and the oldest being seventeen years of age. The longest period of follow-up had been twenty-six months.

In thirty of the feet operated upon, the deformity had been caused by poliomyelitis. The results obtained in this group had been better than those obtained in any other group. In twenty-two of twenty-eight patients the performance of the foot had been improved, this improvement being due to correction of the deformity and to attainment of better stability.

In the seventeen feet with cavus deformities due to causes other than poliomyelitis, the results had been less favorable. In the patients with congenital pes cavus, the results had not been dramatic, but the performance of the foot had been improved in every instance. The authors concluded that patients with congenital pes cavus should be operated upon before they are twelve years of age, by which time the bony structure of the foot has become established. No mention was made, however, of how many patients in this series had been under twelve years of age when operated upon. The authors stated that several years of observation would be necessary before final evaluation of the results in this group could be made.

In the two patients with a residual cavo-adductus deformity following incomplete correction of club-foot, marked improvement had occurred. No improvement had occurred in a patient with a residual deformity following club-foot and arthrogryposis, however, and no improvement had occurred in a patient with pes cavus associated with myelodysplasia.

Further experience must be obtained before it is possible to define the indications for the use of this procedure in patients with pes cavus associated with spina bifida, congenital pes cavus, and Friedreich's ataxia. The youngest age at which this procedure can be applied and the undesirable results which may occur after extensive denervation in a very young child have yet to be clarified. The authors felt that selective plantar-muscle denervation might be a good means of preventing the progressive development of cavus deformities.

*Tibioperoneal Tenoplasty for Treating Certain Cases of Congenital Club-Foot in Young Children.* As an introduction to the problem and, to some degree, as a justification of the surgical procedure advocated, DR. JUAN FARILL[8] mentioned briefly some of the etiological theories concerning congenital talipes equinovarus. He accepted as the most logical of these theories the hypothesis that most club-foot deformities are due to muscular imbalance. Regarding the cause of muscular imbalance, however, he avoided committing himself. Impartially he quoted both advocates of the theory of hypertonicity of the anterior and posterior tibial muscles and proponents of the theory of hypotonicity of the peroneal muscles.

---

[6] 23 East Ohio Street, Indianapolis 4, Indiana.

[7] 10515 Carnegie Avenue, Cleveland 6, Ohio.

[8] Avenue de la Morena 854, Narvarte, Mexico (12), D.F.

On the basis of his long experience in treating the orthopaedic deformities of children, the author recommended the customary plaster-of-Paris cast treatment, emphasizing that early care is important. He stated that many patients with talipes equinovarus are successfully treated by non-operative methods, but he also stated, quoting from Camara, that only about twenty-five per cent of club-foot cases eventuate in satisfactory results. He recommended that his tenoplasty be performed upon: (1) patients in whom passive overcorrection has been obtained but who, in spite of several months of continued orthopaedic and physiotherapeutic treatment, cannot actively maintain a position of overcorrection; (2) children four or more years of age who have had several recurrences of equinovarus deformities following adequate corrections; and (3) patients in whom satisfactory correction has not been attained by non-operative measures. As a contra-indication to performing tenoplasty, he noted that the operation is not feasible if secondary bony deformities have become established. At the same time that he does the tenoplasty, he routinely performs surgical release of soft-tissue contractures on the medial side of the foot; in patients whose feet cannot otherwise be over-corrected, he also performs a lengthening of the Achilles tendon.

The operative technique advocated follows well-established procedures of tendon transfer. Instead of transferring the anterior tibial tendon to a site over the lateral side of the foot, however, a procedure that has become popular in some clinics in recent years, Dr. Farill cuts the peronaeus longus tendon and sews the proximal end of that tendon into the uncut tendon of the peronaeus brevis; he then transfers the severed anterior tibial tendon subcutaneously across the dorsum of the ankle and sews it into the distal stump of the cut peronaeus longus tendon. Following this procedure a long cast is applied with the foot in an overcorrected position. This cast is continued for two weeks, after which time a plaster-of-Paris boot is continued for three more weeks. After removal of the boot, a corrective club-foot-type shoe, with elastic traction, is used during the day, and an aluminum splint, with elastic traction, is employed at night. Physiotherapy is given. The therapeutic shoes and splints are discarded when the foot can actively maintain an overcorrected position.

Dr. Farill's evaluation of the results obtained by sixteen operations performed over a recent six-year period was as follows: one poor, two fair, five good, and eight excellent. He stated that overcorrection never occurred in his series. The period of follow-up had ranged from six months to five years.

*Harold A. Sofield*

*Function of the Peroneal Muscles in the Paralytic Equinovalgus Foot.* Dr. J. Leonard Goldner [9] and Dr. C. E. Irwin [10] emphasized that talipes equinovalgus, occurring in association with weakness of the tibialis anterior, is usually due to a combination of factors rather than to the isolated action of the peronaeus longus. They pointed out that transplantation of the peroneals, either anteriorly or posteriorly, does not result in correction of either the depression of the medial border of the foot or of the cock-up deformity of the big toe. In a foot in which the tibialis anterior is weak and in which the calf muscles are contracted, clawing of the big toe occurs when dorsiflexion is attempted by means of the extensor digitorum communis and the extensor hallucis longus.

If both peroneal tendons are transferred, a dorsal bunion will not occur unless the extensors of the great toe have been moved or are paralyzed and unless the flexor hallucis longus is acting strongly across a relaxed metatarsophalangeal joint. In the authors' series of 117 cases, dorsal bunions had occurred in only two patients. In these patients the extensor hallucis longus had been transferred to the metatarsal neck and the flexor hallucis had been acting across a relaxed joint. The absence of the peroneals from their usual position had had no effect on the development of the bunions.

Transfer of the extensor hallucis longus and fusion of the interphalangeal joint without release of the heel cord, both procedures used to correct cock-up deformity of the big toe in a deformed foot, may result in recurrence of the claw deformity. This result is particularly likely to occur if the procedures are performed in a foot in which the proximal phalanx is held in a fixed position by a tight dorsal capsule. Dropping of the great toe may follow the performance of a Jones suspension, and a hallux rigidus may occur if the tendon is placed in the neck of the metatarsal. The authors stated that indications for the performance of the Jones suspension are limited and that, in their experience, fusion of the interphalangeal joint of the great toe, when done in conjunction with heel-cord lengthening and triple arthrodesis, will usually correct valgus deformity of the foot and clawing of the big toe. Occasionally lengthening of the extensor hallucis longus, lengthening of the heel cord, and fusion of the interphalangeal joint will be sufficient to correct a painful callus under the first metatarsal head. Transfer of the peroneal tendons alone does not seem to have any effect on this deformity.

[9] Duke University Hospital, Durham, North Carolina.

[10] Professional Building, Atlanta, Georgia.

In conjunction with lengthening of the extensor hallucis longus, as well as in conjunction with other essential procedures about the foot, it may occasionally be necessary to perform an osteotomy at the base of the first metatarsal.

The peroneal muscles are strong plantar flexors which act on the entire foot, and under most circumstances they should be transplanted to the os calcis rather than to the dorsum of the foot.

*Tendon Transplantation for Correction of Paralytic Calcaneus Deformity.* Dr. William T. Green[11] and Dr. David S. Grice[12] discussed the poor gait and the increasingly severe deformity which results from talipes calcaneus due to poliomyelitis; they pointed out that it is difficult to correct this condition in older patients. Over a period of twenty-five years they had performed 152 posterior transplants, and they described the results which they had obtained by these operations.

Most of the patients in whom talipes calcaneus had developed had been stricken by poliomyelitis when less than five years of age. In a high proportion of these patients, it had been possible to obtain good stability and to prevent the development of a severe calcaneus deformity by performing transplantation operations within eighteen to twenty-four months after the onset of paralysis. In these operations the available muscles had been transplanted from the front of the foot to the os calcis.

Although formerly it had been considered essential to perform an arthrodesis at the time of transplantation, during the previous six or seven years the authors had performed fewer and fewer stabilizing procedures, and the results they had obtained had seemed to be equally good. Bony stabilization had still been necessary in a certain number of patients, however, as had been expected. For patients requiring early stabilization, the authors recommended that the arthrodesis be extra-articular, and they stressed that the tendon or tendons to be transplanted should be selected with painstaking care.

The importance of fixing the transplant to the os calcis was stressed. In their operation the authors had exposed the os calcis through a transverse incision and had drilled a hole through the apophysis, fixing the tendon through the non-weight-bearing portion. Their early observations had revealed no disturbance of growth. In fact growth had continued, and with growth the mechanical lever action of the transplant had increased.

In this series the most disturbing complication had been the occurrence of dorsal bunions. The procedure recommended for the transplantation of the peronaeus longus was to suture the distal end of this muscle to the peronaeus brevis. In operations upon patients with strong anterior tibials, two possibilities should be considered, primary transplantation of the peronaeus longus posteriorly or its transplantation laterally to the border of the foot. In the authors' series the peronaeus longus had been transplanted to the os calcis in fifty-eight patients in whom the anterior tibial had been strong; in thirty of these patients bunions had developed. Bunions had not occurred, however, in patients in whom the anterior tibial muscle had been absent or weak.

*Robert Lee Patterson, Jr.*

*A Clinical Evaluation of Muscle Transplantation in the Paralytic Foot.* Dr. Lee Ramsay Straub[13], Dr. J. Paul Harvey, Jr.,[14] and Dr. Charles E. Fuerst[15] had undertaken their study of tendon transfers in the paralytic foot because of the rather widespread diversity of opinion among orthopaedic surgeons concerning the value and efficacy of these procedures. In their report, they pointed out that enthusiasm for tendon transplants seems to run in cycles, the methods being sometimes highly regarded and sometimes severely criticized.

They had attempted to review all the service tendon transplants done at the Hospital for Special Surgery from 1935 to the present. Of a total of 332 patients, 158 had been examined by the authors personally and the results in the 175 feet of these patients, upon which 214 tendon transplantations had been performed, had been evaluated.

For purposes of the statistical study, the patients had been divided into seven groups. The results in each group had been analyzed and evaluated from the standpoint of the strength of the transplanted tendon alone and, also, from the standpoint of the condition of the foot as a whole. By this method it had been possible, in a number of instances, to rate the over-all result as entirely satisfactory, even though the transplanted tendon itself was not functioning.

This apparent paradox in end-result rating is easily explainable on the basis of two very important observations made by the authors:

1. Many times the simple removal of a deforming force had been sufficient to provide marked functional improvement in the foot even though the transplanted tendon had not functioned in its new position.
2. In a number of feet in which tendon transfer alone had not been satisfactory, the over-all result had been quite good because of other operative procedures such as stabilization and relief of soft-part contractures.

---

[11] 300 Longwood Avenue, Boston 15, Massachusetts.
[12] 300 Longwood Avenue, Boston 15, Massachusetts.
[13] 535 East 70 Street, New York 21, N. Y.
[14] New York, N. Y.
[15] 40 Battle Park Homes, Columbus, Georgia.

In compiling their tables the authors had rated the results on the basis of a scale from 0 to 4: 4 representing the ideal result; 3, the satisfactory result; 2 and 1, unsatisfactory results; and 0, failure.

In each of the seven groups a careful breakdown had been made of the results from the standpoint of the strength and function of the transplanted tendons and also from the standpoint of the function of the foot as a whole. For a few groups the authors had attempted to find a correlation between the age of the patient at the time of surgery and the result. The results in the seven groups of patients can be briefly summarized as follows:

*Group A.* In seventy patients seventy-five transfers of the extensor hallucis longus into the neck of the first metatarsal with or without interphalangeal fusion (Jones procedure) had been performed. In forty six of the feet there had been no other tendon transfers, but in the remaining feet the following transfers had been performed. In eleven feet the peronaeus longus had been combined with the long toe extensor; in nine feet the peronaeus brevis had been used as an additional transplant; and in three feet both peroneal tendons had been used in combination with the extensor hallucis longus. On two occasions the anterior tibial had also been transplanted and, finally, on four occasions the extensor digitorum longus along with the long extensor of the great toe had been transplanted.

In addition to the tendon operations, foot-stabilization operations had been performed in eighteen of the feet in this group.

From the standpoint of the over-all function of the foot, the results had been entirely satisfactory in fifty-seven feet and had been unsatisfactory in eighteen feet. From the standpoint of the strength and function of the transplanted hallucis longus in its new position, however, the results had been satisfactory in only thirty-eight of the seventy-five feet.

*Group B. Talipes Valgus.* Forty patients had had valgus deformities due to poliomyelitis. The peronaeus longus had been transplanted in twenty-six patients, in nineteen of which triple arthrodeses had also been performed. The peronaeus longus and brevis had been transplanted in ten feet, in nine of which triple arthrodeses had also been done. Transplantation of the peronaeus brevis combined with foot stabilization had been performed upon three feet, and transplantation of the peronaeus tertius and extensor digitorum longus combined with foot stabilization had been performed upon one foot.

In this group the over-all results had been satisfactory in thirty-three feet and unsatisfactory in seven feet. The authors pointed out that the actual strength of the transplanted tendons had not been too important in connection with the over-all results obtained. The importance of stabilization and of the removal of the deforming forces was again emphasized.

*Group C. Talipes Varus.* Eleven tendon transfers for varus deformity due to poliomyelitis had been performed in eleven patients. In seven of these patients the anterior tibial tendon had been used for the transfer, and in four the posterior tibial had been used. In five of the eleven feet, triple arthrodesis had also been done. As regards over-all function, the results had been good in eight patients and unsatisfactory in three. In none of the patients with unsatisfactory results had stabilization been performed, but in five of the eight patients with good results stabilization had been a strong contributing factor.

*Group D. Talipes Calcaneus.* Twelve tendon transplantations for correction of a calcaneus deformity had been performed upon eleven patients. In most of these patients various tendons had been transplanted either singly (four cases) or in pairs (six cases); in two cases three tendons had been transplanted.

Bone surgery had also been performed upon six feet, and the results in all of these feet had been entirely satisfactory. In only three of the six feet upon which tendon transplantation alone had been done had the results been good.

*Group E. Club-Foot.* Twenty-five tendon transplantations for club-foot deformity had been performed upon seventeen patients. In sixteen of these patients the anterior tibial tendon had been transplanted. In the other patient, the extensor digitorum longus to the fifth toe had been used; in this patient the transplanted tendon had failed to function.

Twenty of the twenty-four transplants of the anterior tibial tendon had obtained excellent results; four had not been satisfactory.

*Group F. Cerebral Palsy.* In five of the six patients in this group, the anterior tibial had been transplanted for talipes equinovarus; in the other patient the extensor hallucis longus had been transplanted for a severe cock-up deformity of the great toe.

Only three of the anterior-tibial transplants had been satisfactory, but the one extensor-hallucis-longus transplant had been considered successful even though the interphalangeal joint had failed to fuse solidly and though there had been partial re-growth of the tendon.

*Group G. Miscellaneous Conditions.* In this group of nine patients, twelve tendon transplantations had been performed for a variety of conditions. The results in nine of the twelve feet had been rated as satisfactory.

In their conclusions the authors emphasized their belief that the benefits derived from tendon transplantations are due to the removal of a deforming force almost as often as they are due to the application of a positive force in a new place. They repeatedly emphasized that it is important to perform stabilization of the foot in addition to tendon transplantation in order to obtain a good over-all result.

*C. H. Crego, Jr.*

*Studies on the Fibrogenesis of Collagen.* Dr. Jerome Gross[16] discussed the extensive studies he had carried out in collaboration with Dr. Francis O. Schmitt[17] and Dr. J. H. Highberger[18] on the structure and fibrogenesis of collagen. He defined collagen as that class of fibrous protein which is characterized structurally by a particularly wide-angle x-ray diffraction pattern and by a 640 Angström axial repeating period, and chemically by a high hydroxyproline and glycine content, a low aromatic amino-acid content, and a low sulphur amino-acid content.

It was pointed out that collagen can be dissolved in weak acetic acid and then reprecipitated in its original form by the addition of salt solution. This finding led to the question of the composition of the building blocks from which collagen could be made and to the question of what would stimulate its formation.

When collagen, extracted in acid buffers, had been dialyzed against distilled water, two types of fibrils had been produced. One had been a typical collagen fibril, and one had been a fibril with a relatively long axial period (called "fibrous long-spacing" or F.L.S.). By the use of dialysis, with the proper building blocks but without cells and probably in the absence of enzymes, it had been possible to precipitate highly ordered fibrous structures. Dr. Gross maintained that specificity is inherent in the collagen-building blocks and is not inherent in any of a variety of agents which can induce fiber formation.

The manner in which the fibrous-long-spacing fibrils are formed had been studied by the examination by electron microscopy of the solution dialyzed for varying periods of time.

When adenosine triphosphate had been added to a solution containing dissolved collagen, small 2,600-Angström crystallites, called "segment long spacing" or S.L.S. fibrils, had been precipitated. By special techniques three distinct precipitates can be formed from the same collagen solution: (1) typical collagen fibrils, (2) fibrous long-spacing (F.L.S.) fibrils, and (3) segment long-spacing (S.L.S.) fibrils. Each of these precipitates can be redissolved and converted into any one of the other two forms in a quantitative manner as all three materials are made from the same building blocks. This information had led to the concept that the native structure must be derived from a particle which is 2,600 Angströms long and very thin. It had been named the tropocollagen particle.

In studies on the biological precursors of collagen, the author had extracted skin in cold neutral buffers and had obtained a viscous solution containing collagen. On incubation this solution had formed a stiff gel composed of typical striated collagen fibrils. Since collagen fibrils are not dissolved by salt solutions, this finding led to the supposition that the material came from the extrafibrillary spaces and might represent a precursor of collagen. By the use of these techniques it had been revealed that in the skin of scorbutic animals there is approximately one-sixth as much extractable collagen as there is in normal guinea-pig skin. This condition is probably not specific to scorbutic animals but probably has to do with growth processes and may also exist as a result of certain protein deficiencies.

*The Anatomy of the Lumbosacral Posterior Rami and Meningeal Branches of Spinal Nerves (Sinu-Vertebral Nerves), With an Experimental Study of Their Functions.* After reviewing the literature Dr. Herbert E. Pedersen[19], Dr. Conrad E. J. Blunck[20] and Dr. Ernest Gardner[21] presented the results of their study of the sinu-vertebral nerves. The sinu-vertebral nerves are small. They arise from the spinal nerves and anastomose with the autonomic system as well as with each other. They re-enter the vertebral canal through the intervertebral foramina, first passing upwards around the bases of the pedicles and from thence passing towards the mid-line of the posterior longitudinal ligament. Elements are given off by these nerves to the posterior longitudinal ligament, to the periosteum, to the blood vessels of the epidural space, and to the dura mater. Entry of branches of the nerves into the annulus fibrosis of the intervertebral disc could not be demonstrated.

The anatomy of the posterior rami of the spinal nerves had also been studied and was reported. In these studies both gross specimens and microscopic sections of foetal material had been used.

Experimental studies in the decerebrate cat had been done. In these studies changes in blood pressure, respiration, and reflex muscular activity had been noted after stimulation of the spinal nerves and also after stimulation of the sinu-vertebral nerves and of the areas supplied by these nerves. The authors concluded as follows: "It is suggested that, clinically, a painful stimulus to any deep structure in this region is poorly localized and can give rise to a common symptom complex which includes both low-back pain and pain in the lower extremity (as related to the lumbosacral region)."

*End-Results in Compression Fractures of the Vertebrae with Special Reference to the Intra-Osseous Arterial Circulation.* Dr. Edgar M. Bick[22] emphasized that restoration of the shape of a crushed vertebral body through hyperextension followed by external fixation in a body jacket is "usually ineffective" and "rarely if ever necessary". To substantiate this claim he referred to the clinical experience reported by Nicoll, by himself, by Howarth, and by others. He further claimed that the functional end-results of this treatment bear "little if any relation to the final contour of the affected bone", and in support of this postulate he referred to his own reports and to those of Nicoll and Sandloff.

---

[16] Massachusetts General Hospital, Boston 14, Massachusetts.
[17] Massachusetts Institute of Technology, Cambridge, Massachusetts.
[18] United Shoe Machinery Corporation, Beverly, Massachusetts.
[19] 12 Norwich Road, Pleasant Ridge, Michigan.
[20] University Hospital, 1300 University Avenue, Madison, Wisconsin.
[21] Detroit, Michigan.
[22] 30 East 60 Street, New York 22, N. Y.

Referring to restoration of shape, he said that in the past "correction had not been maintained for a significant duration" and that almost complete loss of correction or "often enough" even further compression had occurred within a year. He stated that the "final contour" obtained was actually not influenced by the type of treatment used or by the patient's age.

He felt that permanent loss of function, when it occurs, is largely due to effects of the injury other than the vertebral-body compression. Among these effects he included adjacent intervertebral-disc disorganization, zygapophysial-joint injury, and injury to vertebral ligaments.

Searching for factors other than the fracturing compression force which are involved in the formation of the "final" wedge shape of the centrum, he had studied "a number of vertebrae", presumably obtaining these vertebrae at necropsy. The centra had been sectioned sagittally and examined in the gross and microscopically. He had found that four arteries enter each centrum through small cortical apertures in the posterior wall, two entering on each side. In addition he had found that many arteries, including the larger ones, pierce the cortex of the centrum anteriorly and laterally and that the largest of these arteries enter through the upper half of the anterior wall. Within the centrum the larger arteries pursue a devious course to reach the core. The core itself, he had found, is "of demonstrably lesser trabecular density" than is the rest of the vertebra, a "primitive medullary space" thus being suggested. To this core, he believes, is directed the arterial flow of the longer vessels and from it the veins pass outward, posteriorly.

On the basis of these findings, Dr. Bick claimed that avascular necrosis and wedging will inevitably occur if the fissures of a crush fracture pass through the medulla-like core of a centrum. If the fissures are limited to the upper third of the body, the final changes will be only minimal. He claimed furthermore that necrosis and wedging will occur regardless of the treatment used, and he declared that "treatment of uncomplicated compression fractures of the spine is chiefly symptomatic and should be so recognized". The possibility that creeping substitution might supervene to preserve the restored contour, he dismissed, feeling that for this to occur the patient would have to devote more time to the avoidance of flexion stresses (between eighteen months and three years) than could reasonably be expected.

With these beliefs in mind, the author advocated that bed rest be continued until pain and disability subsides and that a spinal support then be worn to protect the patient against undue stress and against the effects of early resumption of general activities.

*Circumduction Fusion of the Spine.* DR. DAVID M. BOSWORTH [23] reported the results obtained by fusion of the spine in seventeen patients with mid-line infection of the back or defects of the spine. The type of fusion employed was designed to circumvent the involved area. The fusion was begun in the mid-line above the defect, was extended laterally to the ribs or transverse processes, and was brought back to the mid-line of the spine below the defect. Fourteen of the patients had had tuberculosis, and three of the patients had had instability and pain due to previous extensive laminectomies and facetectomies of the lumbar area. Nine fusions had been done in a single stage; eight had required more than one procedure.

In thirteen patients the fusions had been performed in the thoracic or thoracolumbar area. In this group extremely complicated and severe problems had occurred, but there had been no deaths or wound complications. The largest number of segments fused had been fourteen and the smallest, six. Eleven of the procedures had resulted in solid fusion, and two had resulted in pseudarthrosis. It is noteworthy that eleven of the patients with tuberculous spondylitis had been paraplegic, that five had had draining sinuses and four had had decubitus ulcers, and that eight had previously undergone laminectomies for paraplegia. These thirteen patients had all been extremely ill, many of them suffering from a combination of complications. The fusion procedure had been accompanied by general supportive measures, including the administration of antituberculous drugs (iproniazid had been used in three patients). Twelve of the patients had been living when this report was written, eleven of them having recovered from the paraplegia and one having remained a total paraplegic. One patient had died in an automobile accident. Only two of the patients who had lived had been functionally disabled, while ten had been able to return to work. In none of the patients had the bone grafts been resorbed; in fact, with time, the grafts had hypertrophied. All the sinuses which had existed prior to treatment had healed. The thirteen patients in this group had been followed for from three to nine years, the average follow-up being four years.

Three patients in this series had had disc disease, and in these patients wide laminectomies and facetectomies of the lumbar spine had been performed. One other patient had had tuberculosis. Fusion had been achieved in the patient with tuberculosis and in one of the patients in whom a laminectomy had been done. In the other two patients, pseudarthrosis had persisted. These two patients had become severely addicted to narcotics and had still been disabled when this report was written.

[23] 742 Park Avenue, New York 21, N. Y.

Dr. Joseph C. Risser[24], who discussed this paper, considered the author's fusion operation an ingenious method of immobilizing the spine. He emphasized that stability can be obtained more easily in the thoracic area, where the chest provides support for bone grafts, than in the lumbar area. He said that the results of the author's treatment had been remarkable in that not only had the paraplegic patients lived, but 75 per cent of them had been able to return to work. He added that the author's procedure could be considered as an adjunct to the treatment of severe complications as well as an adjunct to routine mid-line fusions.

*Hydrocortisone Injected into Degenerated Intervertebral Discs.* Dr. Henry L. Feffer[25] reported the results he had obtained in sixty patients with low-back pain by the injection of hydrocortisone into a lumbar intervertebral disc. Using a modification of Erlacher's technique, he had injected the two lowest intervertebral discs with a mixture consisting of three cubic centimeters of 35-per-cent diodrast and one cubic centimeter of hydrocortisone (fifty milligrams). The condition of the disc had then been demonstrated by a roentgenogram (discogram) and note had been made of the volume of solution injected and of the pain caused by the injection, which had been made under moderate pressure. No restrictions had been placed on the patient's activity until after his response to the injection had been evaluated. If a remission of symptoms had occurred, a back support and postural exercises had been prescribed.

Thirty-six of the sixty patients injected either had been in extreme pain before the injection and had not been helped by bed rest or else had demonstrated a sudden progression of neurological symptoms. Seventeen of the sixty patients had had persistent or recurring symptoms in spite of conservative treatment, and seven of the patients had been injected in an attempt to establish a diagnosis.

The complications following the injections had been limited to the occurrence of mild headaches in fifteen patients. The results of the injections had been as follows. For five patients the nucleograms had been normal, and in these patients no improvement had occurred. In thirty-seven (67 per cent) of the remaining fifty-five patients, who had had "pathological discs", remissions had occurred and relief had begun as early as four to six hours after the injection. Follow-up examinations of these patients had shown that in thirty-three of them the remissions had continued for as long as eight months. In the other four, symptoms had recurred within two weeks to four months. In eighteen (33 per cent) of the patients with "pathological discs", there had been no response to the injection. Sixteen of these patients had been explored surgically, and in fifteen of them gross herniations had been found and free cartilage had been observed either in the canals or directly under the posterior longitudinal ligament. In the sixteenth patient surgically explored, the annulus had been intact, but the nerve root had been attached to a protrusion.

Of the thirty-seven remissions, thirty-two had been considered complete and five had been considered partial, the evaluations being based upon the presence of pain, spasm, scoliosis, "sciatic irritability", and neurological symptoms. Abnormal neurological symptoms had occurred in nineteen patients, but in fifteen of these patients the symptoms had later partially or completely disappeared. In 54 per cent of the patients with remissions, the lesions had occurred in the fifth lumbar disc, in 16 per cent the lesions had occurred in the fourth disc, and in 24 per cent the lesions had occurred in both discs. In the remaining patients the lesions had occurred at higher levels. No definite correlation had been found between the duration of the symptoms and the response.

*The Mechanical Response in Normal and Degenerated Lumbar Discs.* Dr. Carl Hirsch[26], Stockholm, Sweden, reviewed the previous work done in Sweden on the problem of low-back pain and reported the results of a current study on the behavior of intervertebral discs after subjection to static and dynamic loads. It had been found that about 65 per cent of the population of Sweden had low-back pain; the incidence of this pain was equal in males and females but it was slightly higher in laborers doing heavy work than it was in the rest of the population. The onset of low-back pain had followed an accident in 20 per cent of the cases studied, had resulted from carrying a heavy object in 20 per cent, and had not been related to any known causative factor in 60 per cent. In an effort to find the pain mechanism, extensive studies had been carried out and electron microscopy as well as biochemical, pathological, and biomechanical techniques had been employed.

As a human being ages, the proteins in the discs increase while the mucopolysaccharides decrease. Associated with these changes is a fall in the water content. The annulus fibrosus of the disc is composed of bundles of collagen fibers attached to both the periphery and the middle of the vertebral plates, and it contains no demonstrable nerve endings. When the human being is over twenty years of age, changes occur in this structure, these changes being characterized by softening of the ground substance and separation of the fiber bundles. By the time the human is thirty years of age, well advanced structural changes have developed in the posterior portions of the lower lumbar discs and in the anterior parts of the upper lumbar and dorsal discs. It has been observed that similar but differently located changes occur in dogs and cows.

---

[24] 2637 East Washington Street, Pasadena 8, California.

[25] 1703 Rhode Island Avenue, N.W., Washington 6, D. C.

[26] Karolinska Institutets Ortopediska Klinik, Stockholm, Sweden.

After a large number of discograms had been made, it had been concluded that there is no correlation between back-pain symptoms and the findings revealed in discograms. Discography had then been abandoned as a diagnostic method. The pain associated with disc puncture had been found to vary according to the location of the needle within the disc, indicating that such pain results from the needle penetrating a sensitive area in the disc. This sensitive area is possibly made up of the granulation tissue which, it had been found, develops in relation to ruptures of the annulus. The pain resulting from the injection of the disc had not seemed to be caused by bulging, for no such deformation had been demonstrated when fresh autopsy specimens had been injected.

Single intervertebral discs had been subjected to static and dynamic loads by means of special devices. The resulting compression and bulging had been recorded by electrical methods. With static loads most of the deformation had occurred within the first half minute, but continual change had been recorded for as long as the load had been continued and absolute equilibrium had never been attained with loads up to 150 kilograms. In both normal and degenerated discs, the bulging had always been less than two millimeters (under the conditions of these experiments). It was felt that this amount could not produce sufficient pressure to cause painful irritation of the dura or nerve roots. When dynamic loading had been applied by means of a falling weight, there had occurred vibrations in the disc which were damped out in less than one second. The amplitude of these vibrations had varied with the conditions of the loading. It was emphasized that a trivial injury to an individual carrying a heavy load might induce vibrations which would deform a disc beyond its elastic limit, with resultant rupture and pain.

When larger loads had been applied, either static (400 kilograms) or dynamic (25 kilograms falling 0.5 meter), fracture of the vertebral plate with leakage of the disc contents into the centrum had occurred, as had been demonstrated by roentgenograms made after the patient had been injected with an opaque liquid. In a patient with an injury caused by lifting, a similar fracture had been demonstrated by means of tomography, conventional roentgenograms having failed to show any abnormality.

The author concluded that backache is not the result of disc degeneration *per se* but is the result of other factors, these factors including fracture of the vertebral plate and growth of granulation tissue into the disc following rupture of the annulus. Statistical studies had seemed to support the latter concept, and a good correlation had been found between the presence of back-pain and the presence of granulation tissue in the annulus, both being most common in patients who were from thirty to fifty years of age. In contrast, the presence of disc degeneration is most common in older people.

DR. ARTHUR STEINDLER[27] discussed this paper, emphasizing its fundamental importance.

*Combined Hip Fusion and Subtrochanteric Osteotomy Allowing Early Ambulation.* DR. FREDERICK R. THOMPSON[28] reported his experience with subtrochanteric osteotomy which he had employed in conjunction with arthrodesis in order to facilitate fusion of the hip in patients with non-tuberculous conditions. The leverage of the femoral shaft is 23 to 1; and, if the knee is extended, the leverage of the limb may be as much as 55 to 1. By the performance of a subtrochanteric osteotomy, this leverage is removed for approximately seven weeks.

The author had begun to develop his method in January of 1946. Since then thirty-five patients had been operated upon, ten of the operations being performed without removal of the articular cartilage. In the technique usually employed at present a Smith-Petersen incision is used to expose the hip joint. A piece of the anterior wing and crest of the ilium, two and a half inches long and including both cortices, is removed as a graft. The femoral head is dislocated, and it and the acetabulum are denuded of cartilage. To allow good contact with the graft, the anterior projection of the femoral head and the prominences of the pubic ramus and antero-inferior iliac spine are removed. The graft is then placed anteriorly against the femoral neck and head, across the acetabulum, and against the pubic ramus. It is secured firmly by five screws. In some instances the graft may lie as far distally as the intertrochanteric line.

The osteotomy is done at the level of or slightly above the lesser trochanter. It should be directed transversely, and there should be no more displacement than is necessary, although some displacement is essential when a marked deformity is being corrected. Care should be taken that the ends of the two fragments at the osteotomy site are completely free so that no femoral-shaft movement can be transmitted to the hip joint. At the close of the procedure a single hip spica is applied with the hip in a position of twenty degrees of flexion, five degrees of adduction, and neutral rotation. Twenty degrees of flexion is secured by holding the limb parallel with the floor while the spica is applied; it is not secured by holding the limb at an angle of twenty degrees with the floor.

The author stated that no more knee motion was attained by exercising the joint through a window cut in the spica than was attained without using this method.

Subtrochanteric osteotomy had been used by Dr. Thompson in patients of all ages, his oldest patient being seventy. In two children the operations had been performed for tuberculosis, previous attempts at fusing the hips having been unsuccessful. In the thirty-five patients reported in this series, the operations had been performed for osteo-arthritis. One of these patients had died two months after the operation, and in the remaining thirty-four patients, the results had been as follows: in three patients, the hip had failed to fuse and in thirty-one the hip had fused solidly. The rate of non-union in this series was 8.8 per cent, whereas in the author's previous series, in which twenty-three operations without osteotomy had been performed, the rate of non-union had been 26 per cent.

---

[27] Marcy Hospital, Iowa City, Iowa.

[28] 16 East 90 Street, New York 28, N. Y.

*Edwin R. Schottstaedt*

*Experiences with Lengthening of the Femur Over an Intramedullary Pin.* DR. FREDERIC C. BOST[29] and DR. LOREN J. LARSEN[30] reported a series of twenty-three operations, performed since January 1951, in which intramedullary nails had been used to facilitate lengthening of the femur. Twenty patients had been operated upon. The authors emphasized that in the past, before intramedullary guidance and support had been used, it had been difficult to control the femoral fragments. The operative procedure for lengthening the femur was described, the reasons for the use of a transverse instead of an oblique or step-cut osteotomy were given, and the soft tissues that need division or lengthening were enumerated.

The operation described by the authors is comparatively simple, but during the postoperative period meticulous supervision is required. The method of applying traction, the rate at which lengthening takes place, the average time necessary for securing optimal lengthening, and the amount of lengthening which can be reasonably expected are all discussed in this paper. As would be expected on the basis of past experience with femoral-lengthening operations, numerous complications occurred in the authors' series. Some of these complications were serious, as the authors frankly stated, and there were several instances of delay in union, this delay sometimes necessitating the implantation of autogenous grafts. There were no deaths, however, and no extremities were lost. It was recorded that a lengthened femur can be successfully relengthened at a later date through an incision made in the same area as the original incision.

This paper should be carefully reviewed by anyone planning to perform a femoral-lengthening operation. The authors felt that the use of their procedure is justified in selected cases and that they were reporting a carefully planned and executed experiment. They indicated that this operation does not completely solve all of the problems involved, but they felt that it does represent a considerable step forward in the successful treatment of patients (mainly children) with shortened limbs.

*Medullary Fixation of Forearm Fractures.* DR. HUGH SMITH[31] reported the results obtained by medullary fixation in 338 patients with 555 fractures of the forearm. This study had been sponsored by the Office of the Surgeon General, and the data had been accumulated from seventeen sources. The investigation had been limited to fractures of the middle three-fifths of the forearm (514 fractures); and the location of the fractures had been as follows: radius, fifty-three cases; ulna, eighty-seven cases; both bones, 415 cases. All the fractures had been complicated, one-half being comminuted or segmental, one-half being open, one-quarter being associated with other fractures in the same extremity, one-fifth being ununited, one-fifth having been treated by delayed nailing (fifteen to ninety days after the occurrence of the fracture), and one-sixth being associated with damage to one or more of the nerve trunks.

In the treatment of these fractures, Rush pins, Kirschner wires, Steinmann pins, Küntscher V nails, and Lottes nails had been used. Thirty-two of the first patients treated had been permitted early motion, but the remainder had been immobilized with plaster-of-Paris, the mean period of immobilization having been ten weeks. The ulna had responded well to medullary fixation, but the radius being curved and having a medulla of varying width had been more difficult to treat in this manner. The duration of immobilization by casts or splints had not been appreciably shortened by the use of medullary fixation, and the functional results obtained by this method of treatment had been only comparable to those obtained by other methods: in 61 per cent of the patients, the results had been satisfactory, and in thirteen per cent, there had been moderate to severe limitation of motion. Because of the presence of non-union or because of inadequate follow-up, the degree of function obtained in the remaining patients could not be analyzed.

Of 176 open fractures, thirteen had become infected and 25 per cent had resulted in non-union. Of 236 closed fractures, five had become infected and 17 per cent had resulted in non-union. In all, 20 per cent of the 514 fractures reviewed had resulted in non-union, the highest incidence of non-union occurring in fractures treated by Kirschner wires (38 per cent) and in solitary fractures of the radius (28 per cent). Bone grafts had been employed in 115 fractures, eleven of the grafts being onlay and the remainder being chip grafts. Ninety-seven of the fractures which had been treated by chip grafts could be analyzed, and in twenty-five of these non-union had developed. It had appeared that grafting by bone chips was not satisfactory for patients with complicated fractures. There had been eight instances of bent pins, seven instances of broken pins, thirty-nine instances of excessive shortening or angulation, and six instances of synostosis.

(*Continued on page 248*)

---

[29] 384 Post Street, San Francisco 8, California.

[30] 52 Mercedes Way, San Francisco 27, California.

[31] 869 Madison Avenue, Memphis 3, Tennessee.

# KELLOGG SPEED

## 1879–1955

With the death of Dr. Kellogg Speed on July 2, 1955, the medical profession lost one of its outstanding leaders of the last generation.

Until a few days before he passed away, at seventy-six years of age, he was apparently in good health. Dr. Speed was internationally recognized by physicians and by laymen as one of the great general surgeons who was interested in orthopaedic surgery, although he preferred to be known as a bone and joint surgeon.

He was born in Cleveland on January 17, 1879, and was graduated *cum laude* from the University of Chicago in 1901 with the degree of B.S. During his undergraduate days, he was one of the great athletes of the University, especially as a football player, and his interest in athletics and in the University continued throughout his life. In 1954, he was given a distinguished service award from the Medical Alumni Association of the University of Chicago, having been previously awarded a citation from the University of Chicago in 1942, and a certificate of appreciation from the American Medical Association in 1951, for his twenty-five years service as Chairman of the Fracture Exhibits.

Throughout the year following his graduation from college he served as a Graduate Fellow in chemistry, and after he received his M.D. degree from Rush Medical College (1904) he spent some time in study at the University of Leipzig and in travel in Russia and the Scandinavian countries.

On completing his internship at Cook County Hospital, he entered practice in Chicago, serving as an Associate in Surgery at Rush Medical College from 1905 to 1908. He then transferred his teaching activities to Northwestern University, advancing from Associate to Associate Professor during the period from 1908 to 1918. He also became an Attending Surgeon at Mercy Hospital.

From 1912 to 1933, he served as an Attending Surgeon at Cook County Hospital, where, with Dr. William Cubbins, he was a prime mover in establishing their Fracture Service. In connection with this service, and following his motto "splint fractures where they are", he was instrumental in having first-aid equipment installed in police cars and ambulances in Chicago.

In 1919, he returned to the Faculty of Rush Medical College as an Assistant Professor, subsequently becoming Professor of Surgery; at the time of his death, he was Professor Emeritus of Clinical Surgery of the University of Illinois College of Medicine (Rush).

Dr. Speed was a member of the Special Committee on Fractures of the American Medical Association from 1936 to 1951, and served as Chairman from 1938 to 1951. He was the Chairman of the Chicago Regional Fracture Committee of the American College of Surgeons for more than twenty years. During this time he also was a member of the National Committee on Trauma of the American College of Surgeons.

He was Attending Surgeon and later Consulting Surgeon at the Presbyterian Hospital and since 1919 Consulting Surgeon at the Highland Park and Lake Forest, Illinois, Hospitals and the Provident Hospital in Chicago.

He also served as a surgical consultant and lecturer at the United States Naval Hospitals in San Diego, California, and at Great Lakes, Illinois, at The Veterans Administration Hospital, Long Beach, California, at The Hoag Memorial Hospital, Newport Beach, California, at The Orange County General Hospital, Orange, California, and was Consulting Surgeon for the Chicago, Milwaukee and St. Paul Railroad.

His term, the "unsolved fracture", by which he referred to the fracture of the neck of the femur, will long be remembered, since his oration before the Clinical Congress of the American College of Surgeons in Boston, in 1934.

Dr. Speed's military service was extensive and comprehensive. He was sent overseas in 1916 with the rank of Honorary Lieutenant Colonel, Royal Army Medical Corps, as head of the Murphy Unit, which was placed in command of General Hospital Twenty-Three British Expeditionary Forces, at Etaples, France.

When the United States entered the war in 1917, he returned as Major, advancing to Lieutenant Colonel, M.C., in charge of the Surgical Division of United States Base Hospital Twelve, which took over General Hospital Number 18, British Expeditionary Force in France, in May 1917. In 1918 he worked in various mobile hospitals and evacuation centers in the Aisne-Marne, Somme, Lys, St. Mihiel, and Meuse-Argonne areas.

The British and United States governments decorated him for his military work.

As an author he published 200 articles on general surgical and orthopaedic subjects, including "Traumatic Injuries of the Carpus" (1925), "The Primer on Fractures of the American Medical Association", "Names of Surgical Operations" (1935), the chapter on general surgery in the *History of Medical Practice in Illinois* (1850–1900), and his textbook *Fractures and Dislocations.*

Membership in Societies:

- American Board of Surgery (Founder)
- American Surgical Association, President 1927–28
- The American Board of Orthopaedic Surgery (Founder)
- Western Surgical Association
- Chicago Surgical Society
- The American Orthopaedic Association
- American Association for the Surgery of Trauma, President 1938–39
- Société Internationale de Chirurgie (Speakers delegate, Paris, 1930)
- Institute of Medicine
- Chicago Pathological Society

Honorary Member:

- Los Angeles Surgical Society
- Seattle Surgical Society
- Omaha Clinical Association
- The American Academy of Orthopaedic Surgeons
- Chicago Orthopedic Society
- Los Angeles Chapter of Western Orthopedic Association

He was also a member of the Board of Governors of the American College of Surgeons and a trustee of Rush Medical College.

Dr. Speed is survived by his widow and five daughters.

# News Notes

The next Annual Meeting of **The American Orthopaedic Association** will be held at the Banff Springs Hotel, Banff, Alberta, Canada, from June 20 to June 23, 1956.

---

The **Clinical Orthopaedic Society** held its Annual Meeting in Oklahoma City, Oklahoma, September 30 and October 1, 1955, under the Presidency of Dr. John H. Moe of Minneapolis, Minnesota. Serving as Vice-President was Dr. Elias Margo of Oklahoma City. Dr. Charles Rountree was Chairman of the Committee on Local Arrangements and Dr. Don H. O'Donoghue was Chairman of the Program Committee.

The Clinical Sessions were held in the University of Oklahoma Medical School Auditorium. The meeting was outstanding and the program was stimulating.

### Friday Morning, September 30, 1955

Welcome. Mark R. Everett, Ph.D., Dean, University of Oklahoma Medical School;
Response. John H. Moe, M.D., President, Clinical Orthopaedic Society;
(1) Benign Bone Tumors. (2) Elbow and Shoulder. (3) Volkmann's Contracture with Wrist Fusion. Willis K. West, M.D., Oklahoma City, Oklahoma;
Diagnostic Problem in the Cervical Spine. John Florence, M.D., Oklahoma City, Oklahoma;
(1) Osteoid Osteoma of the Cervical Spine. (2) A Reconstruction Problem of the Arm. Robert L. Noell, M.D., Oklahoma City, Oklahoma. (The second paper was discussed by Jess D. Herrmann, M.D., Neurosurgeon);
Excision of the Proximal Humerus and Replacement with Vitallium Prosthesis. James C. Amspacher, M.D., Oklahoma City, Oklahoma;
(1) Late Results of Medial Tarsal Osteotomy for Club-Foot. (2) Interbody Infections Following Disc Operations. (3) Some Examples of Leg-Growth Stimulation. Don H. O'Donoghue, M.D., Oklahoma City, Oklahoma;
(1) Hand Prosthesis Demonstrations. (2) The Three-Fingered Hand. William L. Waldrop, M.D., Oklahoma City, Oklahoma;
(1) Fibular Non-Osteogenic Fibroma (Xanthogranuloma). (2) Chondromalacia Patellae, Traumatic. Samuel T. Moore, M.D., Oklahoma City, Oklahoma.
An Unusual Fracture of the Ankle and Foot. Marvin B. Hays, M.D., Oklahoma City, Oklahoma.

### Friday Afternoon, September 30, 1955

Primary (Xanthomatous) Biliary Cirrhosis (Metabolic Studies and Bone Changes). Robert H. Furman, M.D., Oklahoma Medical Research Foundation;
Ferguson Bone Grafts in Delayed Union of Tibia. Frank A. Stuart, M.D., Tulsa, Oklahoma;
(1) An Unusual Case of Non-Skeletal Bone Formation. (2) Humeral-Head Prosthesis. S. Fulton Tompkins, M.D., Oklahoma City, Oklahoma;
(1) End Results in Complicated Fractures Involving the Head of the Humerus. (2) End Results in Bunion Operations. (3) End Results of Hip Prosthesis. Earl D. McBride, M.D., Oklahoma City, Oklahoma;
Ten Years' Follow-up on Hip Reconstruction Operations. John E. McDonald, M.D., Tulsa, Oklahoma;
Hip Reconstructions. Howard B. Shorbe, M.D., Oklahoma City, Oklahoma;
A Complicated Case of Back and Hip Reconstruction. J. R. Stacey, M.D., Oklahoma City, Oklahoma.

### Saturday Morning, October 1, 1955

(1) Cases of Hip Cup Arthroplasties. (2) Other Problems of Reconstruction. Elias Margo, M.D., Oklahoma City, Oklahoma;
Demonstration of Unusual Appliances. Brace Shop, Crippled Children's Hospital;
(1) Myositis Ossificans, Elbow. (2) Rehabilitation Problems. Charles R. Rountree, M.D., Oklahoma City, Oklahoma;
Avascular Necrosis of the Body of the Talus without Fracture. Robert P. Holt, M.D., Oklahoma City, Oklahoma;
Functional Significance of the Level of Paraplegia. Shelby V. Gamble, M.D., Director of Department of Physical Medicine, University Hospitals, and Director of the Oklahoma Institute of Rehabilitation;
Hereditary Congenital Deformities. Marvin K. Margo, M.D., Oklahoma City, Oklahoma;
Dorsalis Kyphosis Juvenilis. Russell Harris, M.D., Oklahoma City, Oklahoma.

Officers elected for 1956 are as follows:

*President:* I. S. McReynolds, M.D., Houston, Texas;
*Vice-President:* Wallace S. Duncan, M.D., Cleveland, Ohio;
*Senior Member, Membership Committee:* Fred Hark, M.D., Chicago, Illinois;
*Regular Member, Membership Committee:* Hira E. Branch, M.D., Flint, Michigan;
*Secretary-Treasurer:* Marcus J. Stewart, M.D., Memphis, Tennessee.

The 1956 Annual Meeting will be held in Cleveland, Ohio.

---

At the meeting of the **American Academy for Cerebral Palsy** in Memphis, Tennessee, October 10, 11, and 12, 1955, Dr. Margaret Jones, University of California Medical Center, Los Angeles, California, was installed as President for the year 1956. Officers elected were:

*President-Elect:* Dr. Nicholson J. Eastman, Baltimore, Maryland;
*Secretary-Treasurer:* Dr. Robert A. Knight, Memphis, Tennessee.

The 1956 meeting will be held in Chicago; the 1957 meeting will be held in New Orleans.

---

The Eleventh Annual Meeting of the **American Society for Surgery of the Hand** will be held on January 27, 1956, in Chicago, Illinois. The final program is as follows:

Osteogenic Sarcoma in the Hand. Robert E. Carroll, M.D., New York, N. Y.;
Use of Single Large Iliac Bone Graft to Replace Multiple Metacarpal Loss. Julian M. Bruner, M.D., Des Moines, Iowa;
Rupture of Extensor Tendons in the Rheumatoid Hand. L. Ramsay Straub, M.D., and Edward H. Wilson, M.D., New York, N. Y.;
Anatomy of the Hand. Ernest W. Lampe, M.D., New York, N. Y.;
Colles's Fracture. Henry C. Marble, M.D., Boston, Massachusetts;
The Carpal Tunnel Syndrome. Bland W. Cannon, M.D., Memphis, Tennessee;
Congenital Deformities of the Hand. Herbert Conway, M.D., and John Bouve, M.D., New York, N. Y.;
Neurovascular Pedicle Transfer of Tissue in Reconstructive Hand Surgery. J. William Littler, M.D., New York, N. Y.;
The Surgical, Social, and Economic Aspects of a Unit Hand Injury. William Metcalf, M.D., and William Whalen, M.D., New York, N. Y.

---

## THE AMERICAN ORTHOPAEDIC ASSOCIATION
## PROCEEDINGS

(*Continued from page 244*)

It was concluded that medullary fixation must be rigid to be satisfactory. It was also concluded that small supple medullary pins should not be used. In the radius these small pins permit collapse of the radial arch with relative lengthening of the bone itself and with consequent distraction and non-union of the fracture of the ulna. The principle contribution of medullary fixation in the treatment of forearm fractures is that it maintains the length and alignment of the bone in the presence of severe soft-tissue damage with minimum risk of infection. This method of fixation is of considerable value in the treatment of segmental and solitary fractures of the ulna. It is less satisfactory for treatment of fractures of the radius, however, and there is need for improvement in the design of the pins and in the technique of their insertion. The final conclusion was that in the treatment of forearm fractures there is a place for closed methods, for plates and screws, and for onlay grafts as well as a prominent but not predominant place for the medullary nail. The indications for the various methods have not yet been established.

DR. G. W. N. EGGERS,[32] in his discussion of this paper, stressed that the treatment of forearm fractures must result in (1) control of the rotatory stresses (sheer) and (2) restoration of bony continuity, especially in comminuted fractures. To achieve these objectives he had used medullary fixation in the radius and a four-inch narrow slotted plate in the ulna. He had also applied plaster casts, continuing them for twelve to sixteen weeks, and had employed long grafts in order to restore bony continuity. In a series of sixty-two fractures of the radius and forty-two fractures of the ulna, eight instances of non-union had occurred, three in the radius and five in the ulna.

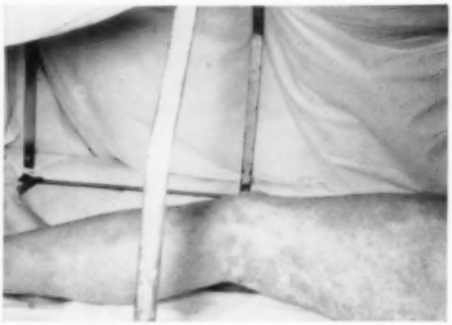
In his reply Dr. Smith stated that he preferred to use a plate in the radius and medullary fixation in the ulna.

---

[32] 2201 Market Street, Galveston, Texas.

*Make pictures like these...*

**For close-ups:** Hold camera so that frame is close to or at the area to be photographed (3⅛ x 4½ inches).



**For arm or leg pictures:** Hold the camera 2½ feet from subject.

**For full- or half-length studies:** Hold camera as indicated by viewfinder.

*Quickly...easily...*

with the Kodak Technical Close-Up Outfit

TECHNICAL
CLOSE-UP OUTFIT

You—anyone on your staff—can master the how-to of this outfit in a matter of minutes. It's specially designed to produce fine-quality record photographs in full color easily and quickly.

Outfit includes Kodak Pony Camera with color-corrected lens, Kodak B-C Flasholder and Kodak Close-Up Flashguards A and B, Portra Lens with fittings, and stainless steel bracket and field frame. Price, $62.50.

Camera loads with 8-exposure No. 828 Kodachrome Film, Type F, or Kodak Ektachrome Film, Type F. The exposed film is returned, processed and mounted, ready for projection.

*Also available*—the Kodak Close-Up Kit to equip other miniature cameras for close-up color photography.

*Price includes Federal Tax where applicable and is subject to change without notice.*

See your Kodak photographic dealer or write for literature.

EASTMAN KODAK COMPANY
*Medical Division*, Rochester 4, N. Y.

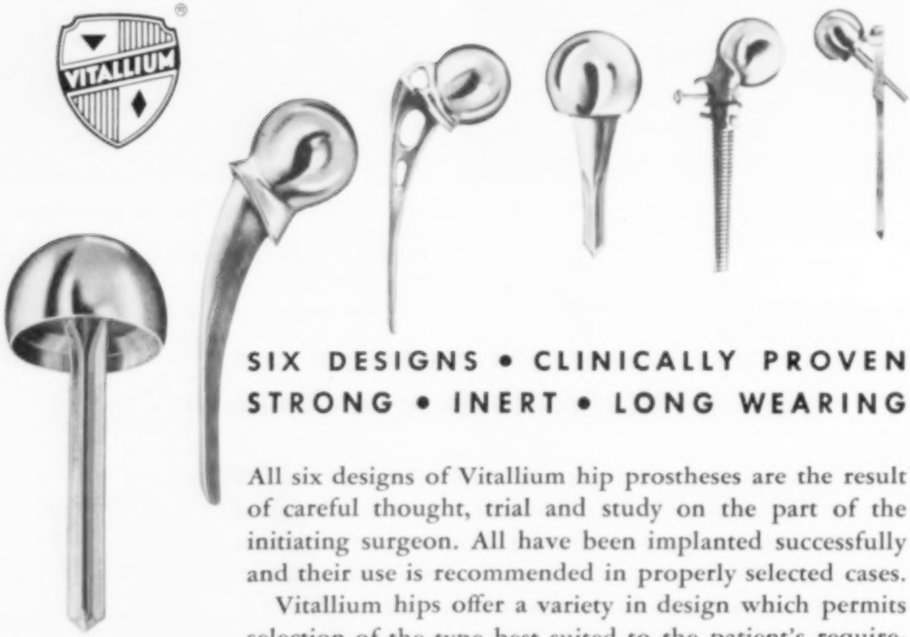
*Serving medical progress through Photography and Radiography*

Kodak
TRADEMARK

## READY-MADE

# Vitallium

## HIP PROSTHESES



**SIX DESIGNS • CLINICALLY PROVEN**
**STRONG • INERT • LONG WEARING**

All six designs of Vitallium hip prostheses are the result of careful thought, trial and study on the part of the initiating surgeon. All have been implanted successfully and their use is recommended in properly selected cases.

Vitallium hips offer a variety in design which permits selection of the type best suited to the patient's requirements. They are strong, well-designed and wear-resistant. The head portions are smoothly polished and except for the Lippmann type are hollow for lightness.

Like all Vitallium appliances, the suitability of these prostheses for permanent implantation has been proven throughout 15 years of use.

* * *

WRITE FOR MORE DETAILED INFORMATION, INCLUDING SIZE DATA AND SUGGESTED OPERATING TECHNIQUES.

**VITALLIUM HIP DESIGNS**

*(from left to right)*

1. Modified Judet Type No. 6902
2. F. R. Thompson Type No. 6936
3. Moore Type No. 6939
4. J. E. M. Thompson Type No. 6938
5. McBride Type No. 6935
6. Lippmann Type No. 6932

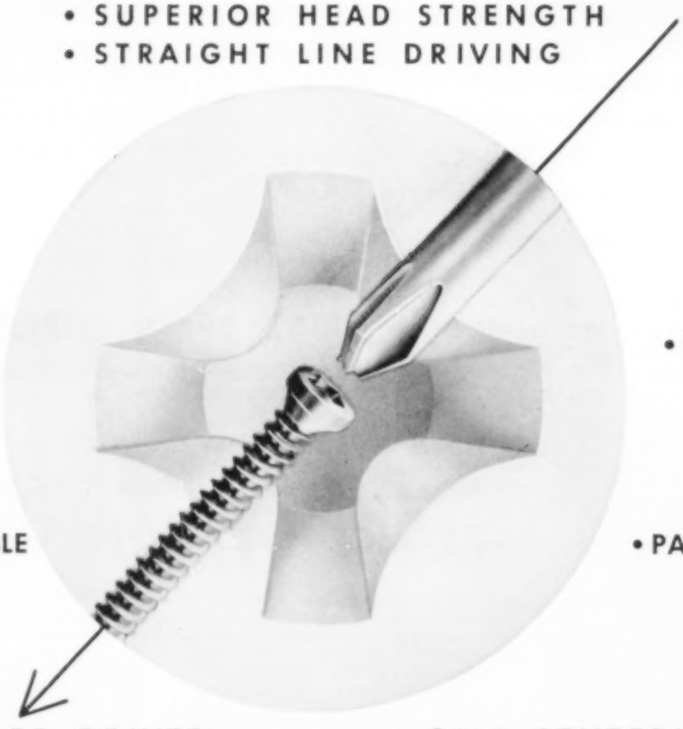
***ORDER THROUGH YOUR SURGICAL DEALER***

**AUSTENAL LABORATORIES, INC.**
**SURGICAL DIVISION**
224 EAST 39th STREET • NEW YORK 16, N. Y.

# Vitallium®

**PHILLIPS** RECESSED HEAD SCREW

- SUPERIOR HEAD STRENGTH
- STRAIGHT LINE DRIVING



- STRONG
- INERT
- COMPATIBLE
- PASSIVE
- RUGGED DRIVER
- SELF CENTERING
- NO DRIVER SLIPPAGE

*Order Through Your Surgical Dealer*

® By Austenal Laboratories, Inc.

AUSTENAL LABORATORIES, INC.
SURGICAL DIVISION
224 EAST 39th STREET • NEW YORK 16, N. Y.

*Reprint, Literature, Measuring Charts and Instructions Upon Request*

# The Jewett Brace . . .

## *for* HYPEREXTENSION OF THE SPINE

COMPRESSION FRACTURES and other cases requiring positive hyperextension such as Osteoporosis with Kyphosis, Adolescent Epiphysitis and Marie Struempell's Spondylitis.

Rigidly performs function of body hyperextension cast; locked on patient when adjusted to proper hyperextension; not removed for bathing or sleeping; adjustable to physical changes, light, clean, sanitary, durable, conducive to physiotherapy and return to light duties.

**FLORIDA BRACE CORPORATION**

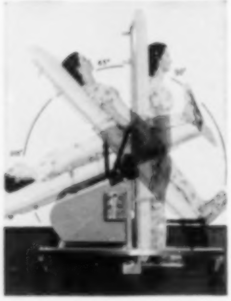
Box 1366, 1151 Harmon Avenue  Winter Park, Florida

---

## Now! One Unit Does the Work of Three

## ★ Standing ★ Oscillation ★ Traction

# RE-MOBILIZATION TABLE



• Standing • Oscillation • Traction

Provides a New Approach for the Rehabilitation of your Severely Disabled Patients through Tilt Table Therapy and early Ambulation. The new Re-Mobilization Table is completely automatic and electrically controlled.

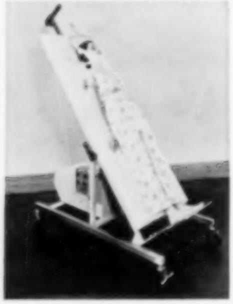
### Here's Every Feature You Could Ask for:

**STANDING** From 205 degrees reverse vertical to 90 degrees vertical . . . the Re-Mobilization Table provides a full range of 115 degrees in both supine and prone positions.

**OSCILLATION** Selective-Intermittent oscillation at the arc prescribed with time delays of ten seconds to three minutes is accomplished automatically and dependably.

**TRACTION** Sustained-Intermittent pelvic traction from zero to 300 pounds, as prescribed. Exact number of pounds is registered on easy-to-read eye level scale. Under perfect control.

Prone Lumbar Traction



Strong Cervical Traction

The Re-Mobilization Table will *increase* the number of patients your department can schedule for treatment each day and *decrease* the amount of work necessary to administer this treatment.

**THREE MODELS AVAILABLE.** Write today for complete information and price list.

**MURKA MANUFACTURING COMPANY**

201 South Main St.  Phone Michigan 7679  Dayton 2, Ohio

Pat. Pending on all features

make this your Guide

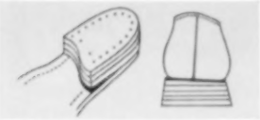
*when recommending Shoes...*

# Poll-Parrot Guide-Rite

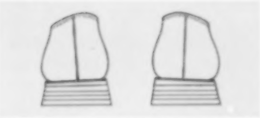
SHOES FOR BOYS AND GIRLS

*Prescribe your adjustments on a sound foundation:*

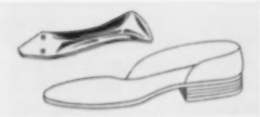
**Poll-Parrot Guide-Rites with these *Tru-Guide* features:**



TRU-GUIDE BROAD-BASE LEATHER WEDGE HEELS BUILT FOR EASY ADJUSTMENTS



INDIVIDUAL LEFT AND RIGHT QUARTERS CONFORMING TO CHILD'S ANKLE BONES

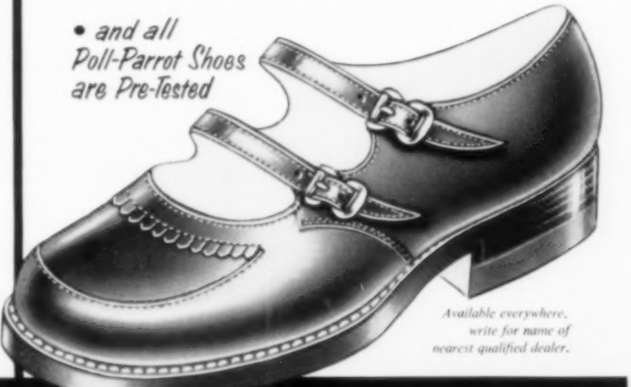


BUILT WITH MOLDED STEEL SHANKS AND EXTRA-LONG LEATHER INSIDE COUNTERS

Fine Goodyear Welt Construction
Top-Grade Waterproofed Leather Soles

*with the* **construction features you want** *plus* **the styling mama wants!**

When you say "*Poll-Parrot Guide-Rite*", here's what you're recommending: Shoes that are made by people who know children's *feet* as well as shoes. Shoes that are developed by pedic *specialists*, are made on the finest-fitting lasts anywhere. Are quality built, quality controlled, every step of the way. And are Pre-Tested by real boys and girls. For, into each pair go all the experience, resources, skill . . . *and vast research facilities* . . . of the *world's largest* shoemaker! And, when prescribing Orthopedic adjustments, specify Poll-Parrot Guide-Rites with the famous Tru-Guide features shown at left.



*• and all Poll-Parrot Shoes are Pre-Tested*

*Available everywhere, write for name of nearest qualified dealer.*

## Poll-Parrot Guide-Rite

*"Just what the Doctor ordered"*

**ROBERTS, JOHNSON & RAND**

Division of International Shoe Company, St. Louis 3, Mo. Makers of Poll-Parrot and Scamperoo Shoes for children; Rand and Randcraft Shoes for men and boys; Trim Tred and Helter Skelter Shoes for women; Star Brand and Hy-Test Work Shoes; and Official Boy Scout and Girl Scout Shoes.

**CORNELL UNIVERSITY MEDICAL COLLEGE**

*announces*

a Postgraduate Course in

**THE TREATMENT OF FRACTURES AND OTHER TRAUMA**

*at*

The Hospital for Special Surgery
NEW YORK HOSPITAL
Cornell Medical Center
**June 4-9, 1956**
in New York City

This six-day course will be given by members of the Cornell University Medical College faculty, serving on the staff of the Center hospitals. In addition to fractures and dislocations, the course will offer a comprehensive review of the treatment of other traumatic conditions, including burns, shock, hand injuries, and trauma to abdomen, chest, and nervous system.

Living accommodations will be available to postgraduate students and their wives in the Cornell Medical College Student Residence, Olin Hall.

TUITION: $150.00—Enrollment Limited

*For further information write to:*

DR. PRESTON A. WADE
Cornell University Medical College
1300 York Avenue
New York 21, New York

THE MONTREAL GENERAL HOSPITAL

*Orthopaedic Course*

Examination preparation for Orthopaedic Certification or Fellowship in the Royal College of Surgeons of Canada given by members of the Department of Orthopaedic Surgery of the Montreal General Hospital.

The first part of the course consists of a weekly reading list covering consecutive phases of orthopaedic surgery, and a written question which is corrected and returned to the candidate with comments. General surgery can be included for the Fellowship candidates if desired. The second part of the course is optional and consists of practical teaching starting in Montreal in August.

*Tuition Fees:*

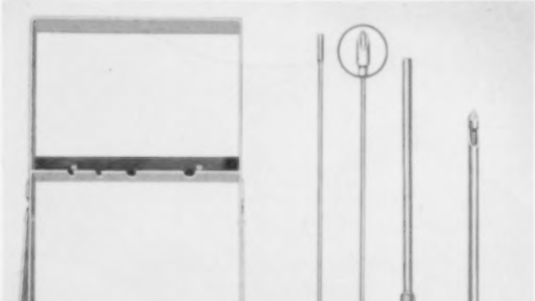
PART I—$150.00 PART II—$75.00
COMBINED COURSE—$225.00

*Apply to:* The Registrar, Postgraduate Board

**THE MONTREAL GENERAL HOSPITAL**
**1650 Cedar Avenue, Montreal 25, P. Q.**

**PUNCH BIOPSY INSTRUMENT for SYNOVIAL MEMBRANE**

***As Described by Drs. H. F. Polley and W. H. Bickel, Rochester, Minnesota***



Permits a relatively simple means of obtaining an adequate specimen of synovial tissue from knee, elbow or shoulder, with little inconvenience to the patient . . .

No restrictions of patient's activity are necessary; ambulatory patients examined under local anesthesia can promptly resume their previous activity. Physical therapy can be begun or resumed within twenty-four hours of the procedure . . .

*Complete, stainless, in rack,*

*Each, $57.50*

Technic is described in Volume I, Number VII, of ARMAMENTARIUM. Your copy will be sent promptly upon request. Ask for it today.

**V. Mueller & Co.** ***Instrument Makers to the Profession Since 1895***
**330 South Honore St., Chicago 12, Illinois**

BRANCHES NOW IN DALLAS AND HOUSTON, TEXAS—ROCHESTER, MINN.

house of BIDWELL inc.

To serve your complete needs in
ORTHOPEDIC, PROSTHETIC
and SURGICAL APPLIANCES

**house of BIDWELL inc.**

535 N. 27th Street
Milwaukee 8, Wis.

*Branch:* 1134 Regent St.
Madison, Wisconsin

for continuing health and vigor
in the "second forty years"

**"MEDIATRIC"®**
STEROID-NUTRITIONAL COMPOUND

IN PREVENTIVE GERIATRICS

AYERST LABORATORIES • New York, N. Y. • Montreal, Canada

Ayerst

A MODERN CORRECTIVE SHOE
FOR EVERY *Orthopedic* NEED

**TARSO SUPINATOR®**
For the postural
correction of
flat feet.

**TARSO
PRONATOR®**
For club feet and
metatarsus varus.
Pairs or single shoes.

**TARSO MEDIUS®**
Straight, neutral last shoe.
Detailed to match Tarso
Pronator. Pairs or single
shoes.

Tarso shoes are fitted on prescription at better shoe stores.
Write for nearest dealer or use your regular supplier.
Brochure on request.

M. J. **MARKELL** SHOE COMPANY, INC.
332 S. Broadway, Yonkers, N. Y.

THORNTON PLATES FLANGED NAILS
for
Treatment of Fractures of the Femur and Trochanter

Grooved Nail
Cannulated Nail
Solid Nail
PLATE ANGLE

**Price Filler Machine & Mfg. Co.**

508 Rorer Avenue, S. W.
ROANOKE, VIRGINIA

IN THE HOSPITAL
Hydrocollator Master Unit maintains ready supply
IN THE HOME
Heat in any vessel on stove
UL
NO WRINGING
NO DRIPPING
WRAP IN TOWEL
30 MINUTES MOIST HEAT WITH EACH APPLICATION
APPLY

EFFECTIVE
MOIST HEAT
EASILY APPLIED
HYDROCOLLATOR
Steam PACK

Everyone agrees moist heat is most effective in reducing spasm and pain. Now it can be easily and efficiently applied! Hydrocollator Steam Packs require no wringing, won't drip, are easy to prepare and handle. In use in leading hospitals and treatment centers.

WRITE FOR DESCRIPTIVE FOLDER

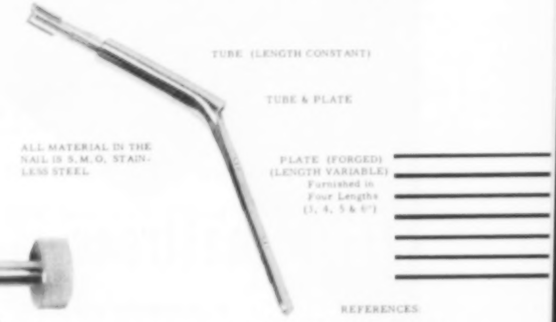
**CHATTANOOGA PHARMACAL COMPANY, INC.**
CHATTANOOGA 5, TENNESSEE

# THE PUGH HIP-NAIL

PAT NO. 2 702 543

*Only* 4 SIZES REQUIRED

*'Self Adjusting'*



ALL MATERIAL IN THE NAIL IS S.M.O. STAINLESS STEEL

The nail is so constructed that only the plate length needs to be varied as adjustability of the nail adapts the appliance for use in almost all fractures about the upper end of the femur. This feature reduces the nail inventory. The unusual strength and adjustability offers additional advantages.

THE NAIL AND THE DRIVER ARE CANNULATED

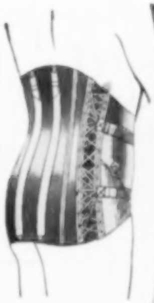
DRIVER WITH REMOVABLE SLEEVE (FURNISHED AS AN ASSEMBLY)

REFERENCES

THE JOURNAL OF BONE
AND JOINT SURGERY
37-A:1085–1093, 1955

MANUFACTURED BY
## KEN STANDARD CORP.
EVANSVILLE, INDIANA

---



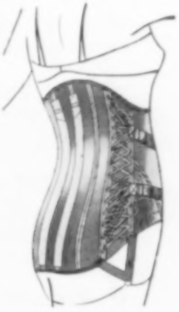
FOR MEN

YOU CAN PRESCRIBE

*Freeman*

**BACK SUPPORTS**

WITH CONFIDENCE



FOR WOMEN

By working closely with the medical profession for over 60 years, Freeman has developed a complete line of surgical supports. From this line you can select and prescribe with complete confidence in the suitability of each garment for its purpose, in the quality of its construction and in the comfort it will give the wearer.

Freeman corset-type back supports are made in models which provide supportive and conservative measures in any required degree to almost complete immobilization. The great advantage of this type of garment is that *it can be worn comfortably while sitting, standing or lying.* In addition to correct design and fine construction, Freeman supports embody many improvements, to increase comfort and convenience for the wearer. For example, linings and stay covers are cushioned for comfort. All side-laced back supports have Freeman's exclusive self-smoothing, nonwrinkle fly.

Mail coupon for details of Freeman quality feature and free pocket-size reference catalog.

**FREEMAN MANUFACTURING COMPANY**
**DEPT. 701 STURGIS, MICHIGAN**

Please send details on new Freeman features and include free reference catalog.

Name______________________________

Address____________________________

City____________________State________

VITAGENIC!

THE
PRESCRIPTION-
BUILT

EXTRA-FIRM mattress

Made according to the exact requirements of the physician or registered orthopaedic specialist! Designed to relieve the backache of spinal or sacro-iliac injury!

CHECK THESE FEATURES:

✓ A rigid mattress and boxspring combination requiring no interposed boards.

✓ Hand-stitched sidewalls so firm it permits patients to get in and out of bed easily.

✓ Resilient surface — provided by curled hair — will not tend to stop circulation or cause undue pressure on nerve points.

✓ Guaranteed for 15 years.

✓ Created by King Karpen, originator of the world-famous Hollandaire mattress — long the first choice of fine hotels.

CONTACT YOUR NEAREST
AIRELOOM DEALER OR WRITE:

Aireloom BEDDING
created by king karpen
1119 Westminster Ave., Alhambra, Calif.

Available • NOW • the Improved

Frejka

ABDUCTION PILLOW SPLINTS

For congenital dislocation of the hip in the newborn and in early postnatal life. (As described by Dr. V. L. Hart, J. Bone and Joint Surg., Vol. 31-A, pp. 357–372, April 1949, and J.A.M.A., August 12, 1950, Vol. 143, pp. 1299–1303.) (See also Orthopaedic Appliances Atlas, Vol. 1 — 1952.)

*Three Sizes:* SMALL — up to 3 months; MEDIUM — 3 to 6 months; LARGE — over 6 months.

*With the new WETPROOF Pillow*
*One or two Halters*

*Choice of colors:* white, yellow, and pink. Orders filled immediately — shipped postpaid.

MINNESOTA ORTHOPEDIC SERVICES
1963 Carl Street
ST. PAUL 8, MINNESOTA

## OUT OF PRINT

THE FOLLOWING back issues are wanted by other surgeons. Some have been waiting years for certain numbers. If you have serviceable copies which you will send to *The Journal* office, we will pay one dollar for each.

1939 — Vol. XXI — Nos. 1, 2, 3, and 4 — all issues.
1940 — Vol. XXII — No. 1 — January only.
1941 — Vol. XXIII — No. 1 — January only.
1944 — Vol. XXVI — Nos. 1, 2, 3, and 4 — all issues.
1945 — Vol. XXVII — No. 2 — April only.
1947 — Vol. XXIX — Nos. 1, 2, 3 — January, April and July.
1948 — Vol. 30-A — No. 1 — January only.

### ALSO WANTED

All issues of *The American Journal of Orthopaedic Surgery*, 1903–1918.
All issues of *The Journal of Orthopaedic Surgery*, 1919–1921.

BONE GRAFTS
NOW AVAILABLE
FOR
IMMEDIATE
DELIVERY

★

*For Information*
*Write to*

**THE NATIONAL BONE AND**
**TISSUE LABORATORIES**
*P.O. Box 529*
HOUSTON 1, TEXAS

*ACTIVE HAND and*
*FINGER SPLINTS*

**Instruments for Hand**
**Surgery and Treatment**

*AS DESIGNED BY*

Dr. STERLING BUNNELL

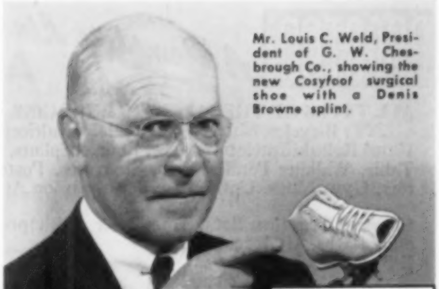
**Carried in stock for immediate delivery**

- Knuckle bender splint
- Radial palsy splint
- Finger extension splint
- Hand Drill w/Jacobs chuck
- Tendon stripper set
- Gig pull-out suture and

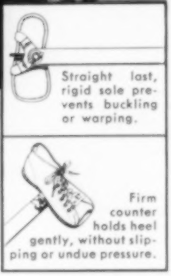
**other special instruments for**
**bone and joint surgery**

▶ *Write for catalogue — postage prepaid* ◀

**H. WENIGER**
*Established 1907*
**143 Valencia Street, San Francisco 3**



**Mr. Louis C. Weld, President of G. W. Chesbrough Co., showing the new *Cosyfoot* surgical shoe with a Denis Browne splint.**



Straight last, rigid sole prevents buckling or warping.

Firm counter holds heel gently, without slipping or undue pressure.

**"here's a surgical pre-walker your patients can afford to buy"**

"It's usually a problem and a hardship for parents to meet the expense of corrective shoes.

"This was brought home to me very clearly when one of my daughter's children needed a surgical shoe. I was amazed at the high price she had to pay . . . and decided to do something about it.

"We put all 57 years of our shoe-making experience into designing a brand-new surgical shoe without sacrificing quality. Your patient can afford to buy it and it is available to them at a low price. We can offer parents a real *help*—and make those parents your friends for years to come.

"Let me tell you about the new *Cosyfoot* surgical. It's designed for use with or without Denis Browne or night splints. It's a pre-walker on a straight last. The open toe allows for normal growth. You can see toes are correctly aligned. You can make sure the heel is set fully down in the shoe.

"Notice the toe area is as wide as the ball measurement. This allows the foot to grow straight, without pressure from inner or outer edge. *This shoe is made to hold its shape.*

Write for a desk sample of these moderately priced surgicals. Examine them at our expense. Send us your name and address and I will send you a sample by return mail."

**MAIL COUPON now for free desk sample**

**G. W. CHESBROUGH, INC.**
**797 SMITH STREET · ROCHESTER 6, N.Y.**

NAME.................................................
ADDRESS.............................................
CITY....................................................

**PRESTON** *A Complete Line* **FOR PHYSICAL MEDICINE AND REHABILITATION**

**ALL TYPES OF THERAPEUTIC EXERCISE EQUIPMENT:** Bicycles, **Shoulder Wheels.** Quadriceps Boots, **Hand Rehabilitation Devices,** Bunnell Splints, Kanavel Table, Walking Parallel Bars, Staircases, Posture Mirrors, **Gym Mats.** Guthrie-Smith Suspension Apparatus.

**Cervical Traction Sets,** Tractolator, **Whirlpools,** Paraffin Baths, **Hydrocollator.**
**E & J Wheelchairs**
Walkers, Patient Lifters,
Self-Help Devices.

We supply all equipment for setting up a complete Rehabilitation Program, and will gladly assist you in its planning.

***Write for your free copy of our new illustrated Equipment Manual #1056***

**J. A. PRESTON CORP.**
**175 FIFTH AVENUE, NEW YORK 10, N. Y.**

**BOSTON ARTIFICIAL LIMB CO., Inc.**
**69 Canal St., Boston, Mass.**
***Tel. La 3-6548***

**CERTIFIED PROSTHETISTS**

*supplying your complete prosthetic needs*

**ARMS:** From SHOULDER DISARTICULATION (with B. A. L. Co.'s method of abduction) to TRANSMETACARPAL AMPUTATION.

**LEGS:** SUCTION SOCKET and other types of PERMANENT LIMBS made of Willow, Plastic and Aluminum.

**OLDEST AND LARGEST LIMB MFG. CO. *in* NEW ENGLAND**

**CERVICAL TRACTION UNIT**

***(Complete as Illustrated)***

No. 121A, adult
$17.00

No. 121B, youth
$17.00

No. 121C, child
$17.00

•

*Set consists of the following:*

1 Head Halter
1 Weight Carrier
5 Two-lb. Weights
10-foot Traction Cord
1 Door Traction Unit

***Above will fit any door. Padded to prevent marring.***

**RAJOWALT CO.**
**ATWOOD, INDIANA**

*Manufacturers of Fracture Equipment*
SOLD ONLY THROUGH SURGICAL DEALERS
*Catalog Sent Upon Request*

**WILLIAMS**
**LUMBO-SACRAL BRACE**

Measurements: 1. Chest (about 4" below nipple line); 2. Waist (at navel line); 3. Pelvic (½ distance between greater trochanter and crest of ilium); 4. Seventh cervical spinous process to sacrococcygeal junction.

**ALL ORTHOPAEDIC APPLIANCES**

**Orders filled at the request of members of the profession only**

MILLER BRACE CO.
3902 Gaston Avenue Dallas, Texas
For prompt service use our P. O. Box 7902

Make Your Own
Orthopaedic Appliances

*with the new DIREKT-FORM*

*Cervical collar shown here was designed and constructed of Direkt-Form by A. Orthopedic Appl. Co., 450-2nd, N.Y.C.*

DIREKT-FORM aluminum-alloy wire and woven fiber mesh is a new, patented material. The mesh is easily formed directly to the body of the patient. This molded form is then dipped into the plastic hardener. Also, the DIREKT-FORM method has a unique advantage over plaster. A special softener is supplied which permits reshaping or adjustment of a semifinished or finished DIRECT-FORM device.

*Write today for Bulletin of Technique*

*These are important DIREKT-FORM features:*

- ✓ Eliminates plaster casts
- ✓ Can be handled at room temperature
- ✓ Simple technique
- ✓ Light-weight and durable
- ✓ Readily reshaped
- ✓ Allergy-proof, easily sterilized
- ✓ Radiolucent
- ✓ Cosmetically more appealing to patient

**DIREKT-FORM**

**153 Hackensack Avenue, Hackensack, N. J.**
EXCLUSIVE NATIONAL FRANCHISES AVAILABLE—for many countries. Write for proposal.

---

*Where traction is indicated use . . .*

**tractolator***

**MOTORIZED INTERMITTENT TRACTION**

*Reg. U.S. Patent #2633124—2633125

Now the physician can administer a carefully graduated, smooth traction force . . . precisely, automatically . . . intermittently, with maximum comfort to the patient . . . of greater traction force than ever before—up to 50 lbs. cervical, up to 100 lbs. pelvic!

As illustrated, TRACTOLATOR is made in both chair and bed models, the latter for bed patients and hospital cases. Bed traction is used for pelvic traction and can be adapted for cervical traction by using a single pulley and cable with head halter attachments.

**VISIT**
**Booth #51**
A.A.O.S. Convention
Palmer House
Chicago
Jan. 28–Feb. 2
1956

**Distributed Exclusively by**
**LOUIS YELLIN, INC.**
242 S. 17th St.
Philadelphia, Pa.

**Manufactured by**
**TRACTOLATOR COMPANY, INC.** 242 S. 17th St. Phila. 3, Pa.

PHYSICAL THERAPY

*For Treatment of* SPASTIC CASES • CEREBRAL PALSY • STROKE
POLIO • HAND INJURIES

***General Electric Company's***

**Silicone BOUNCING PUTTY**

*DOES NOT HARDEN . . . LASTS INDEFINITELY . . . CAN BE AUTOCLAVED*

As a "*TRIAL ORDER*" — **Send $2.00 for One $2.85 Jar**

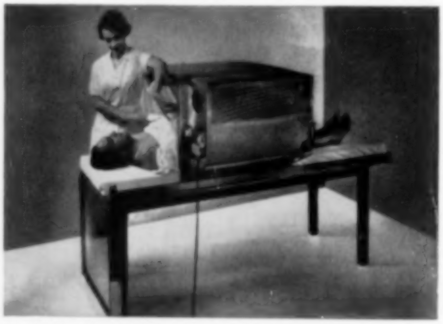
**S. R. GITTENS,** *Sole Distributor* • 1620 Callowhill Street, Phila. 30, Pa.

*Clarks promise*

**Clarks promise freedom from all foot troubles caused by footwear, if from babyhood none but Clarks shoes are worn, fitted by Clarks Footgauge.**

Clarks back this promise with 129 years of shoe craftsmanship. They *keep* it by making children's shoes which are based on the natural shape of a child's foot . . . in different widths to each length size . . . fitted with scientific accuracy on a special Footgauge for *length*, for *breadth* and for *girth*.

MADE BY C. & J. CLARK LIMITED
(WHOLESALE ONLY), STREET, SOMERSET



**MOISTAIRE**

The Original Heat Therapy Unit

**UNEXCELLED**

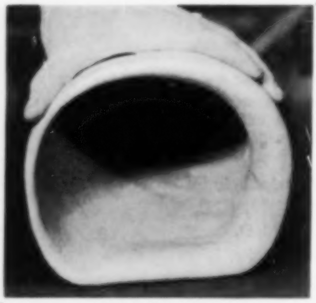
for the delivery of moist heat at the exact prescribed temperature.

COMFORT • SAFETY • DURABILITY

**MOISTAIRE** previously accepted and approved since 1944 by the Council on Physical Medicine and Rehabilitation (AMA). Continued approval by Underwriters' Laboratories since 1944.

*For Illustrated information write, wire or call:*

*The* **RIES** *Corporation*


PAT. NO. 2253040

**THE UNITED LIMB AND BRACE CO., INC.**

15 BERKELEY STREET BOSTON 16, MASSACHUSETTS
Telephone: HAncock 6-4018

*Manufacturers of*

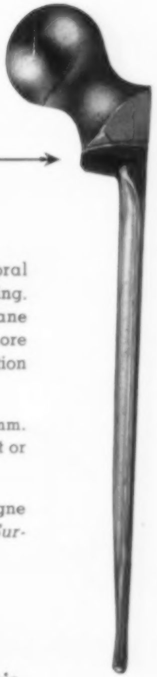
*Artifical Limbs*

This shows how the
***Soft Back Rubber Cushion Socket***
conforms to the stump when the patient is sitting down

CERTIFIED

# IMPORTANT MODIFICATION

*in the LEINBACH-J. GOSSET type Intramedullary Femoral Head-Neck Prosthesis*



No. M-1778
in
Stainless Steel

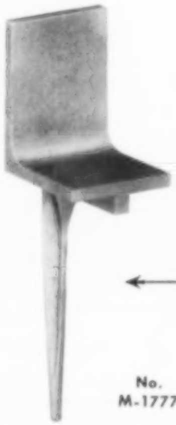
The new small bar on the base prevents any movement of the prosthesis

**ADVANTAGES:** • Restores normal length of femoral head and neck. • Eliminates torsion and tipping. • Allows distribution of pressure in a vertical plane over a large surface and weight bearing at a more vascularized part of the femur. • Allows reconstruction of normal anteversion. • Less bone absorption.

**STANDARD HEAD SIZES:** 43 mm.—45 mm.—47 mm.—49 mm. Stem length: 8 in. or 20 cm. Eccentric right or left stem upon order.

**TECHNIQUE:** Refer to paper by R. Merle d'Aubigne and M. Postel, *The Journal of Bone and Joint Surgery,* 36-A, No. 3, 451–475, June 1954.

***NEW***



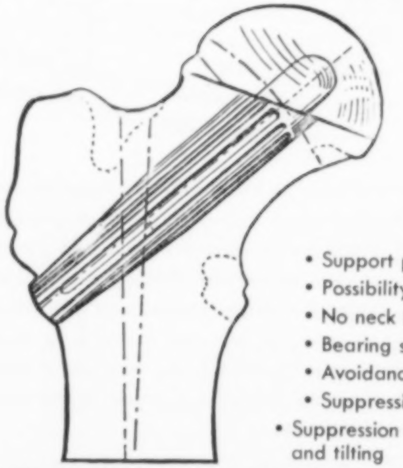
No.
M-1777

## *TRIAL SETTING DEVICE*

**for M-1778 LEINBACH-J. GOSSET prosthesis.**

Insures accurate placement of the prosthesis before final setting.

## ALSO

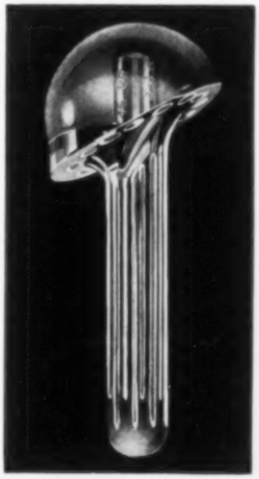


## JUDET *Oblique Plane* FEMORAL HEAD

No. M-1760 (SMo steel)
No. P-1760 (Ossacryl)

**ADVANTAGES**

- Support plane near the horizontal
- Possibility of vascularization
- No neck reaming necessary
- Bearing surface doubled
- Avoidance of shearing stresses
- Suppression of necrosis
- Suppression of rotation, loosening, and tilting

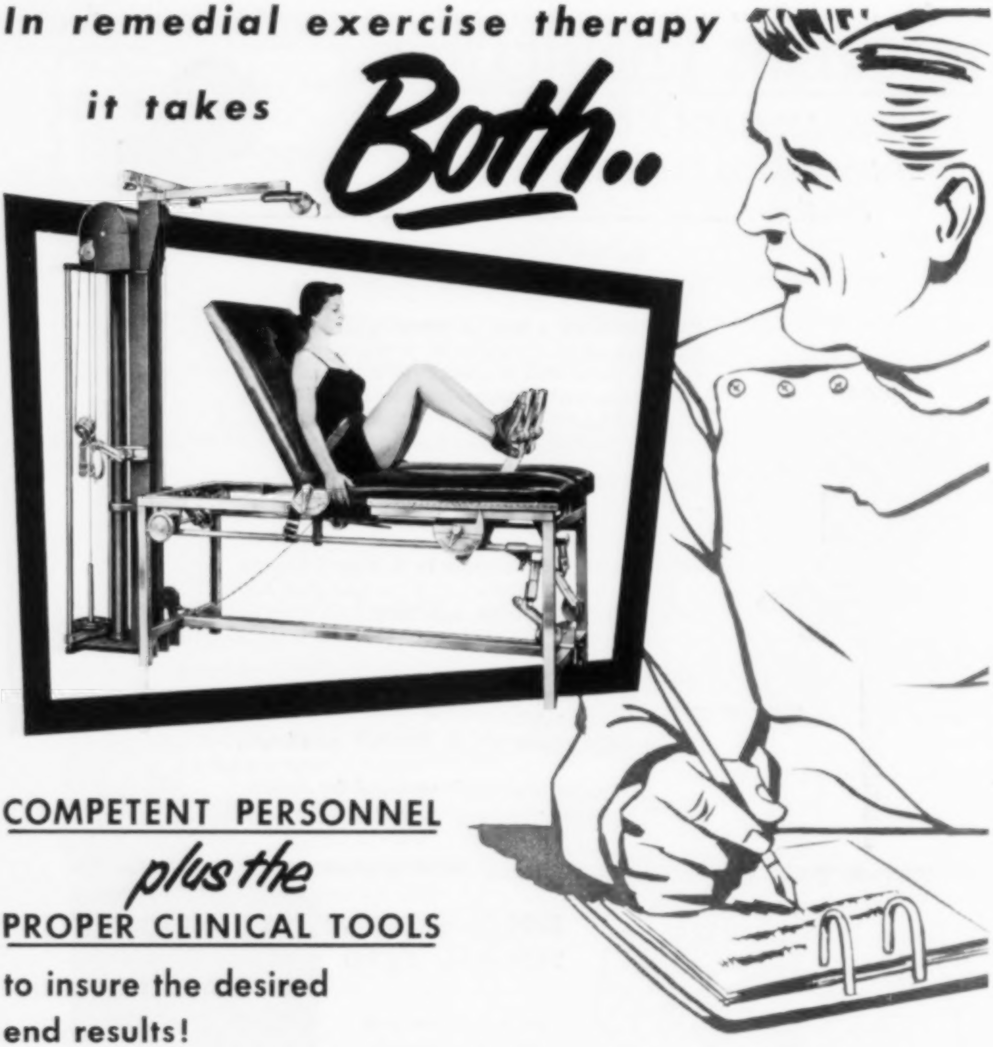


## AMERICAN OSSACRYL COMPANY

15 Park Row
New York 38

**In remedial exercise therapy**

**it takes *Both..***



**COMPETENT PERSONNEL**

*plus the*

**PROPER CLINICAL TOOLS**

**to insure the desired end results!**

MANUFACTURERS OF
REMEDIAL EXERCISE EQUIPMENT

The Elgin Exercise Appliance Co. has specifically designed and developed, in a scientific manner, a complete line of progressive resistance exercise equipment to meet the many and varied problems of remedial exercise therapy. This equipment gives the doctor and technician the proper clinical tools with which to administer a great variety of remedial exercises for both the surgical and non-surgical patient. It also provides a wide exercise range, from simple functional exercises to the most highly definitive focal exercises.

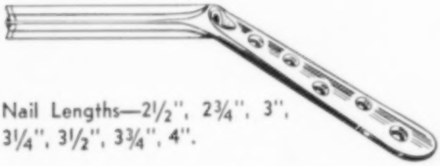
WRITE TODAY for available information that will give you a better introduction to this equipment and what it can do for you.

**Elgin EXERCISE APPLIANCE CO.**

**P. O. BOX 132, DEPT. A · ELGIN, ILLINOIS**

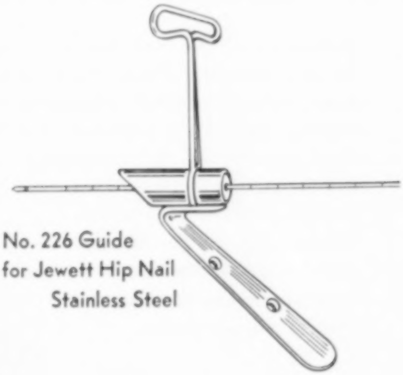
*Jewett* ONE-PIECE NAIL . . .
AND COMPLETE SET OF INSTRUMENTS.

No. 224J—Jewett One-Piece Hip Nail. Drop forged SMO Stainless Steel—Cannulated.

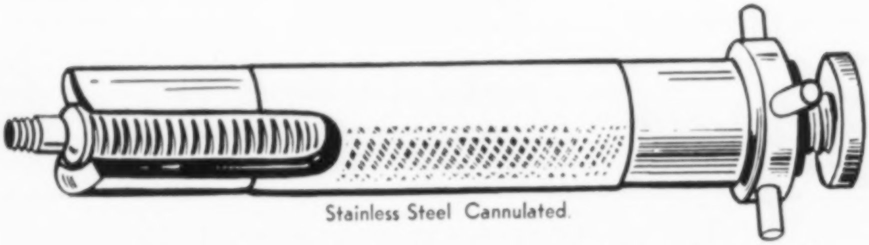


Nail Lengths—2½", 2¾", 3", 3¼", 3½", 3¾", 4".

Plate Lengths—4", 5", 6".



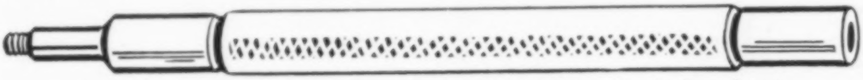
No. 226 Guide for Jewett Hip Nail Stainless Steel



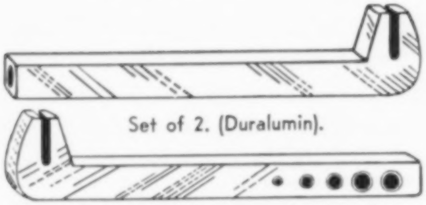
Stainless Steel Cannulated.

No. 208J Extractor-Impactor for Jewett One Piece and Smith Petersen Hip Nails.

No. W402J Henderson Cortex Reamer. Cannulated. Fits Jacobs Chuck. Stainless Steel.



No. 225 One-Piece Nail Driver. For Jewett Nails. Stainless Steel. Cannulated.



Set of 2. (Duralumin).

No. 219J Jewett Nail Plate Bending Irons.

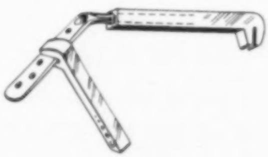


*Illustration shows one of many uses of plate bending irons.*

WRIGHT MANUFACTURING COMPANY

739 JACKSON AVENUE • TELEPHONE 37-2769 • MEMPHIS 5, TENNESSEE

NEW *Fillauer* NIGHT SPLINT

**DETACHABLE — DENNIS BROWNE TYPE**

Orthopedic surgeons are even more enthusiastic about the new, improved Fillauer Night Splint. This versatile splint affords decided advancements for treating club feet, positional deformities, tibial torsions, flat feet, congenital hip dislocations, and any other deformities that are actively corrected by incessant kicking. Use of the Fillauer Splint minimizes the necessity of manipulations, plaster, tenotomies and anesthetics.

● Stainless bronze serrated discs permit 50 different rigid settings. FITS ANY SHOE—the new triple flange lateral clamp permits secure attachment to clubfoot shoes or any thickness of sole. Best results are confined to children under 3 or 4.

WRITE FOR DESCRIPTIVE FOLDER

*Fillauer* SURGICAL SUPPLIES, INC.
Box 1678, CHATTANOOGA, TENNESSEE
*Manufacturers of Orthopedic Appliances* ESTABLISHED 1914

## List of Advertisers — January 1956

| | PAGE |
|---|---|
| Aireloom Bedding Company | 46 |
| C. H. Alden Shoe Company | 14 |
| American Ossacryl Company | 51 |
| Astra Pharmaceutical Products, Inc. | 36 |
| Austenal Laboratories, Inc. | 38, 39 |
| Ayerst Laboratories | 43 |
| Bauer & Black, Div. of The Kendall Co. | 29 |
| The Berivon Company | 22 |
| Boston Artificial Limb Co., Inc. | 48 |
| Bowen & Company, Inc. | 34 |
| S. H. Camp and Company | 27 |
| Chattanooga Pharmacal Company, Inc. | 44 |
| G. W. Chesbrough Co. | 47 |
| C. & J. Clark Limited | 50 |
| Codman & Shurtleff, Inc. | 10 |
| Cornell University Medical College | 42 |
| Davis & Geck, Inc., a unit of American Cyanamid Company | 23 |
| DePuy Manufacturing Co., Inc. | 19 |
| Direkt-Form Company | 49 |
| Eastman Kodak Company | 37 |
| J. Edwards Shoe Company | 31 |
| Elgin Exercise Appliance Co. | 52 |
| Fillauer Surgical Supplies, Inc. | 54 |
| Florida Brace Corporation | 40 |
| Freeman Manufacturing Company | 45 |
| S. R. Gittens | 50 |
| Grune & Stratton, Inc. | 32 |
| Hanger Prostheses | 30 |
| Herbst Shoe Manufacturing Company | 26 |
| House of Bidwell, Inc. | 43 |
| Johnson & Johnson | 11 |
| Ken Standard Corp. | 45 |
| Kleistone Rubber Company, Inc. | 18 |
| M. J. Markell Shoe Company, Inc. | 43 |
| The S. E. Massengill Company | 6, 7 |
| Medical Research Specialties | 8 |
| Miller Brace Co. | 48 |
| Minnesota Orthopedic Services | 46 |
| The Montreal General Hospital | 42 |
| V. Mueller & Co. | 42 |
| Murka Manufacturing Company | 40 |
| National Bone and Tissue Laboratories | 47 |
| Orthopedic Frame Company | 24 |
| Pfizer Laboratories, Division, Chas. Pfizer & Co., Inc. | 33 |
| J. A. Preston Corp. | 48 |
| Price Filler Machine & Mfg. Co. | 44 |
| Rajowalt Co. | 48 |
| Richards Manufacturing Company | 12, 13 |
| The Ries Corporation | 50 |
| Roberts, Johnson & Rand, Div. of International Shoe Co. | 41 |
| I. Sabel, Inc. | 16 |
| Chas. A. Schmidt Surg. Inst. Co. | 28 |
| The Selby Shoe Company | 9 |
| Sharp & Dohme, Inc., Division of Merck & Co., Inc. | 21 |
| Smith, Kline & French Laboratories | 25 |
| Smith & Nephew, Inc. | 35 |
| Thompson Bros. Shoe Co. | 16 |
| The Tower Company | 17 |
| Tractolator Company | 49 |
| Truform Anatomical Supports | 15 |
| The United Limb and Brace Co., Inc. | 50 |
| United States Manufacturing Company | 20 |
| H. Weniger | 47 |
| Wright Manufacturing Company | 53 |
| Zimmer Manufacturing Co. | 4, 5 |

## ADDRESSES OF CONTRIBUTORS

## JANUARY 1956

George N. Austin, M.D., Division of Orthopaedic Surgery, The Johns Hopkins Hospital, Baltimore 5, Maryland
R. G. B. Bjornson, M.D., 5536 Queen Avenue South, Minneapolis 10, Minnesota
David M. Bosworth, M.D., 742 Park Avenue, New York 21, N. Y.
Frederick S. Craig, M.D., 622 West 168th Street, New York 32, N. Y.
Paul H. Curtiss, Jr., M.D., 2065 Adelbert Road, Cleveland 6, Ohio
Rex L. Diveley, M.D., 4312 Nichols Parkway, Kansas City, Missouri
George O. Eaton, M.D., 4 East Madison Street, Baltimore 2, Maryland
Rose Elliott, B.A., O.T.R., Gonzales Warm Springs Foundation for Crippled Children, Gonzales, Texas
Albert B. Ferguson, Jr., M.D., Children's Hospital, 125 De Sota Street, Pittsburgh 13, Pennsylvania
W. R. Fischer, M.D., 55 East Washington Street, Chicago 2, Illinois
Lee T. Ford, M.D., 45 Greenacres, St. Louis 15, Missouri
Ben Fox, M.D., 205 N. Van Buren Street, Marion, Illinois
George J. Garceau, M.D., 23 East Ohio Street, Indianapolis 4, Indiana
Charles H. Herndon, M.D., 2065 Adelbert Road, Cleveland 6, Ohio
J. Albert Key, M.D. (Deceased)
Richard H. Kiene, M.D., 4312 Nichols Parkway, Kansas City, Missouri
Barnard Kleiger, M.D., 1150 Fifth Avenue, New York 28, N. Y.
Duane LaViolette, B.S., University of Washington School of Medicine, Seattle 5, Washington
Philip O. Lichtblau, 517 27th Street, West Palm Beach, Florida
Ralph T. Lidge, M.D., 840 South Wood Street, Chicago 12, Illinois
W. B. Looney, M.D., Massachusetts General Hospital, Boston 14, Massachusetts
Robert McClintock, M.D., State University of Iowa, Iowa City, Iowa
Wallace E. Miller, M.D., 23 East Ohio Street, Indianapolis 4, Indiana
Ignacio V. Ponseti, M.D., Department of Orthopaedic Surgery, State University of Iowa, Iowa City, Iowa
Robert D. Ray, M.D., University of Washington School of Medicine, Seattle 5, Washington
Gorton Ritchie, M.D., Department of Pathology, Milwaukee Children's Hospital, Milwaukee, Wisconsin
Mr. D. Roux, 79, de Villiers Street, Johannesburg, South Africa
L. A. Shepanek, M.D., 55 East Washington Street, Chicago 2, Illinois
Wayne O. Southwick, M.D., Division of Orthopaedic Surgery, The Johns Hopkins Hospital, Baltimore 5, Maryland
O. Sherwin Staples, M.D., Hitchcock Clinic, Hanover, New Hampshire
Marcus J. Stewart, M.D., 869 Madison Avenue, Memphis 3, Tennessee
Frederick R. Thompson, M.D., 16 East 90th Street, New York 28, N. Y.
Duncan M. Thomson, M.D., Department of Biology, Whitworth College, Spokane, Washington
J. E. M. Thomson, M.D., 1000 South 13th Street, Lincoln 8, Nebraska
G. T. du Toit, F.R.C.S., 79, de Villiers Street, Johannesburg, South Africa
Kenneth Van Lente, Ph.D., Department of Chemistry, Southern Illinois University, Carbondale, Illinois
R. E. Wells, M.D., 308 Medical Arts Building, Atlanta 8, Georgia
Odon F. von Werssowetz, M.D., Gonzales Warm Springs Foundation for Crippled Children, Gonzales, Texas
Philip D. Wilson, M.D., 535 East 70th Street, New York 21, N. Y.
Randolph N. Witt, Certified Orthotist, Gonzales Warm Springs Foundation for Cripplied Children, Gonzales, Texas
Norvelle K. Wolff, M.S., University of Washington School of Medicine, Seattle 5, Washington
Francis G. Zeier, M.D., Gas and Electric Building, Rockford, Illinois

RUMFORD PRESS
CONCORD, N. H.